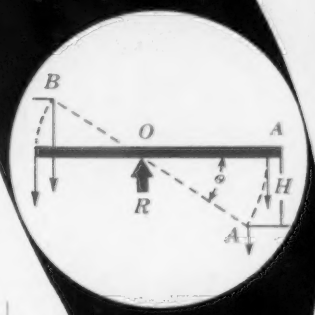
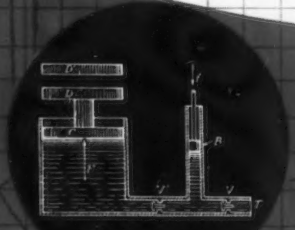
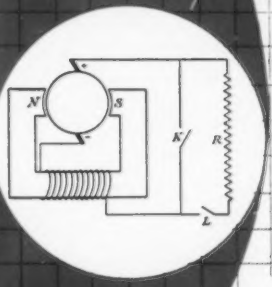
AIRCRAFT AND MISSILES MANUFACTURING

A CHILTON PUBLICATION

MAY 1959







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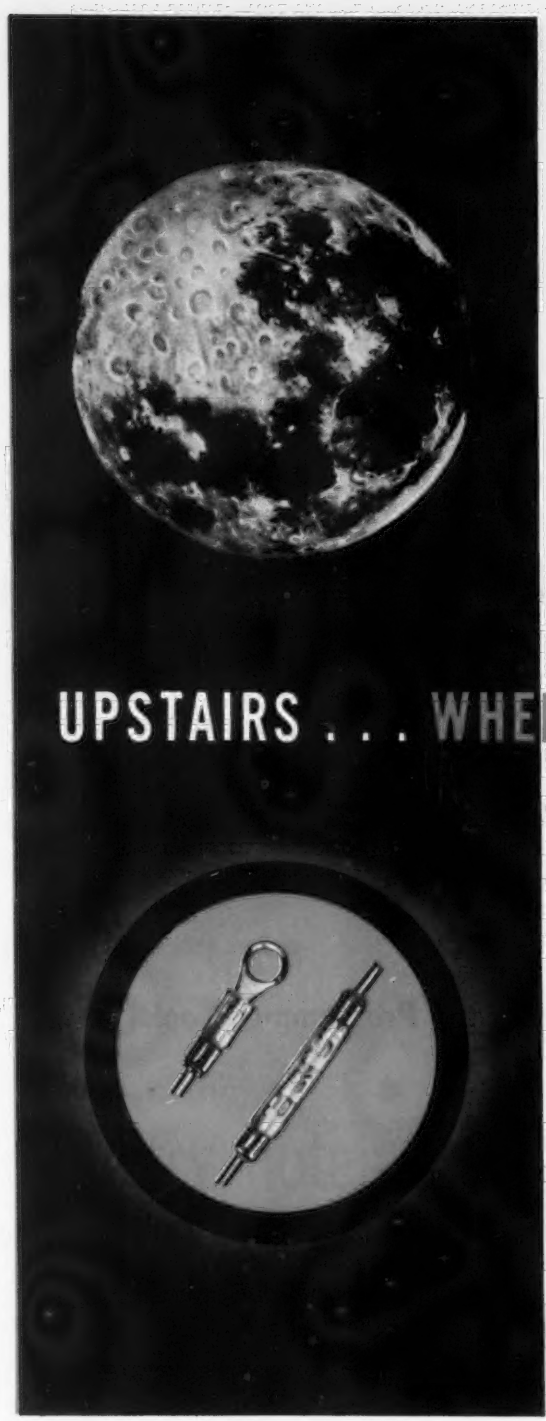

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THE COVER STORY

Man's puny physical strength has been a poor match for the forces of Nature. Realization of this handicap has motivated him to seek phenomena for meeting Nature on her own terms. The behavior of fluids under pressure, the advantages of the lever, and the latent power of the electron have been utilized to develop separate, useful packages. Airborne hydraulic-systems represent the optimum integration of these applications.

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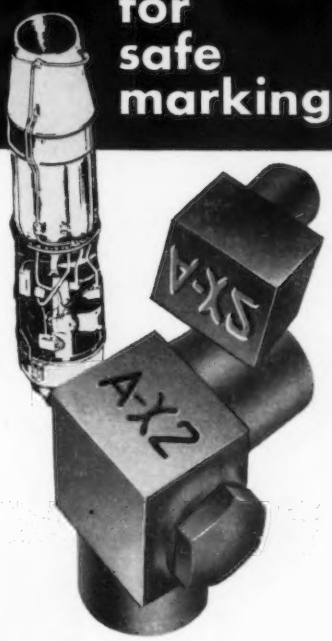

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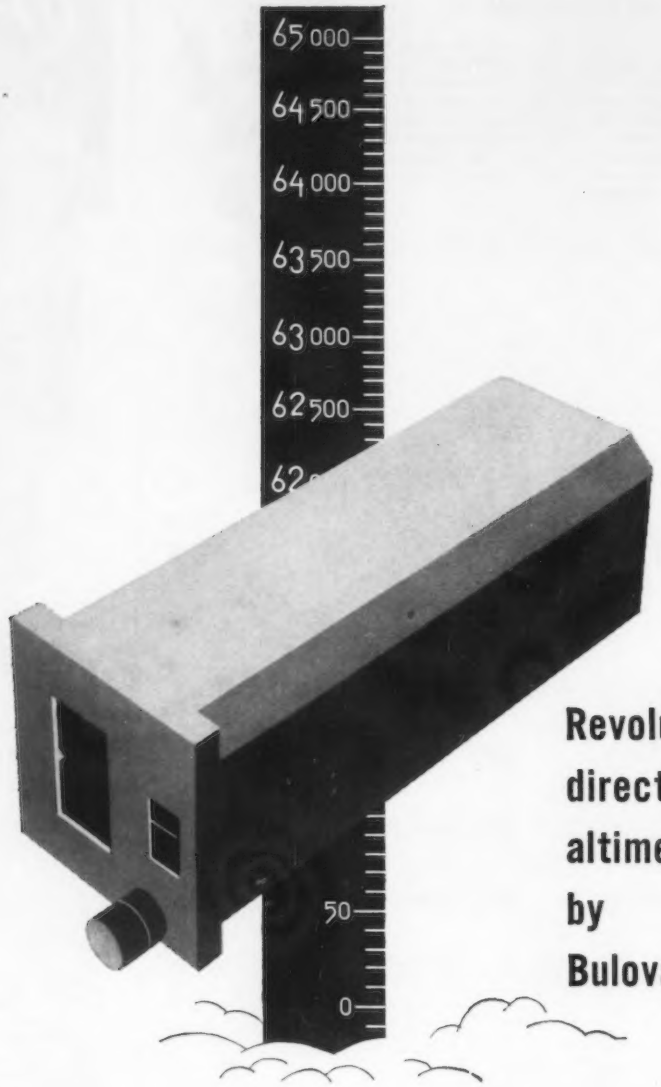

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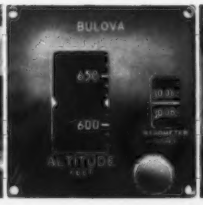

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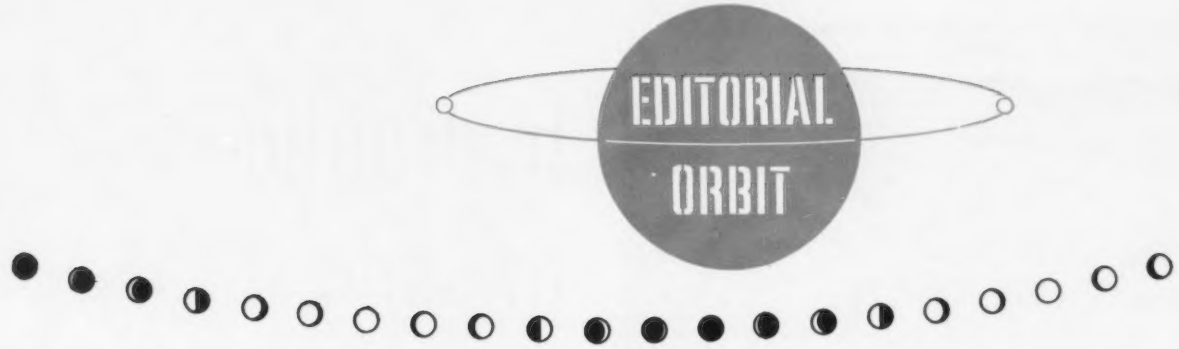

share the know-how

Back to the old theme—integration of the manufacturing team. What's it about this time? Contracts, money, and manpower.

Here's the story! A few years ago, one of the large aircraft makers was given a sizeable research contract. Project was completed—then no more funds. Decision—abandon project. The engineers—laid off.

Now, almost one year later, the boys at DOD say "go to work." The product is needed, but where are the information and the people? Neither is available.

Where are the records, the research reports? We all know where such things wind up on discarded projects—buried amid the paper files. Usually the round variety. Who can find them? And furthermore, who would recognize them if they did find them? The only people in the know are those who worked on the project, but they're not around.

Almost every research project, even though closed out, should add to our technological knowhow; the money spent should not be a total loss.

With our case-in-point, however, the money, and the knowledge as well, were a total waste. Next question?

How can the company, now, successfully build the product without the know-how of the men on the original project? Simple answer—more money. This is real waste.

Research or experimental programs paid for out of tax money, when cancelled, should be either turned over to industry at-large or be given to contracting organization's manufacturing team. Then, this accumulated knowledge can be used for current or future design, production, or procurement practices. If results are made known, perhaps other contracts might be fulfilled more economically.

Industry should keep its manufacturing team abreast of the experimental programs. Then, others can help evaluate projects and, you never know, perhaps add some experience.

Information is what the manufacturing team needs to help get new contracts, make more money, and save manpower.

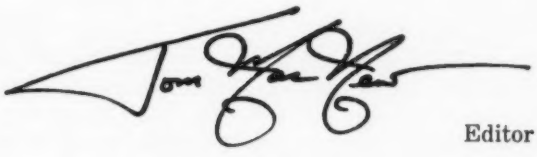

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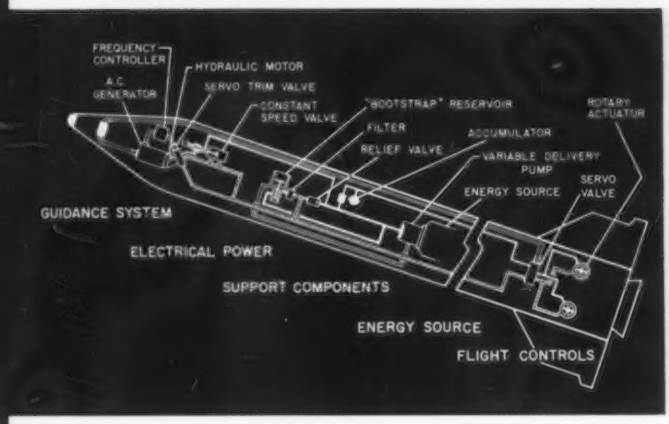
Fig. 1. Schematic of typical simplified missile hydraulic system.



hydraulic missile-components

a look at some hardware that symbolizes three development goals in missile hydraulics; reduced size and weight, extended temp operation, and improved reliability

by **Arthur B. Billett**, senior staff engineer, Vickers Inc.

The mission requirements of current and future missiles demand accuracies in control system response not believed possible a few years ago. For this reason, the accessory power equipment has assumed major importance in design and development, to the extent that the airframe is relatively a secondary item.

In the problems relating to missile hydraulic components and systems, development work has been speeded to:

- Reduce the size and weight of equipment.
- Provide operation at higher temperatures.
- Improve reliability.

This latter area, that of reliability, is one of paramount importance. It has been stated that in one of our major ICBM's, there are about 300,000 separate components. To have 9 out of 10 successful missions requires a total reliability of 99.999 per cent.

Environmental conditions, which components must operate at, range from those which have been common in the past few years, to the so-called hyper environments. These generally include environments existing above 15 mi altitude and at speeds in excess of Mach 5. Both natural conditions and induced conditions cause these environments.

The natural ambients of interest are: (1) ozone content (100 times that at sea level), (2) extremely low pressures, (3) disassociated gases (atomic oxygen), and (4) radiation (solar).

Induced environments include: (1) temperature extremes (increasing from −65 to 1200°F in a few minutes), (2) accelerations (up to 60 g's), (3) vibration (up to 40 g's at 2000 cps), and (4) zero gravity.

Hydraulic Power Package

Typical of missile hydraulic systems is the simplified schematic in Fig. 1. The first problem is to design, test, and produce individual valves, and reservoirs; the next is to package them together in a working unit called a "hydraulic power package."

The power package, shown in Fig. 2, is now in quantity production for a ground-to-air missile application.

The design objective of the power package is to integrate as many components as possible in order to eliminate external lines and fittings, which become possible sources of leaks. A second

major consideration is a saving of space and weight. This particular package consists of four (4) sections:

THE POWER PUMP CONTROL SECTION, consisting of a pump, relief valve, unloading valve, speed control, speed sensing unloading valve and check valve. The 3000 psi hydraulic pump is driven at 10,000 rpm by an ethylene oxide-energized turbine and provides a 2 gpm flow.

THE ACCUMULATOR RESERVOIR SECTION, consisting of a high pressure piston type unit which utilizes system hydraulic pressure through a differential area piston to provide pressurization for the inlet of the pump.

THE FUEL RESERVOIR, which is a hydraulic pressurized tank similar to a piston type accumulator. Ethylene oxide is withdrawn from the larger of two cylinders by forcing hydraulic fluid under 3000 psi pressure into the smaller cylinder.

THE CONTROL PANEL SECTION, which contains an air gage, air fill quick-disconnect, two low pressure relief valves, oil fill quick-disconnect, fuel fill quick-disconnect, oil bleed connection, fuel indicator, oil indicator, filters and panels.

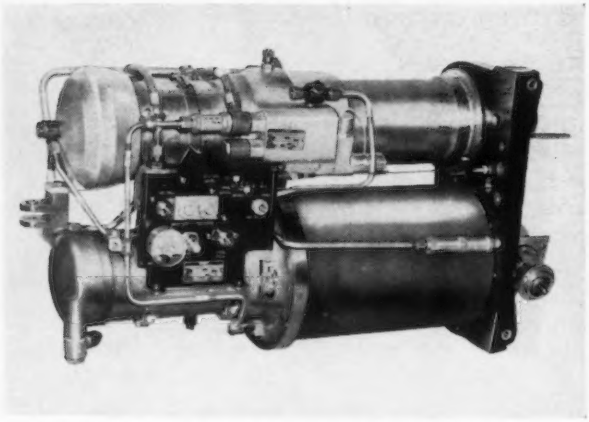


Fig. 2. Hydraulic power packs similar to this unit for ground-to-air missile bring many units together for ease of servicing and increased reliability.

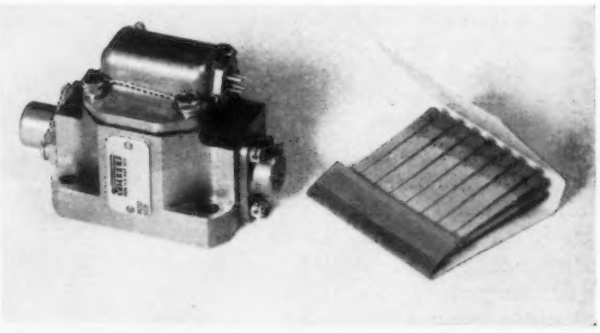
Missile System Development

Many other types of missile packages and missile systems are under development and study.

continued on next page

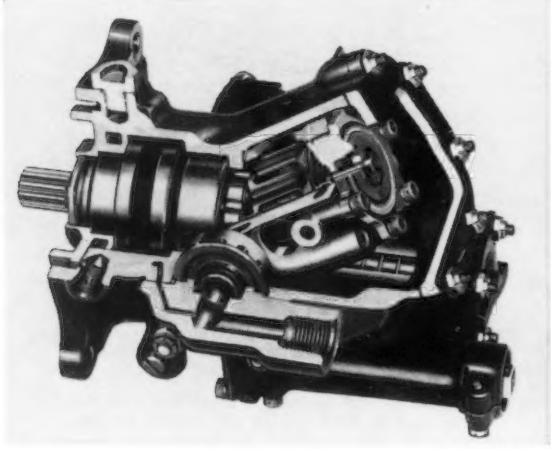
MINIATURIZATION

Two-stage, electro-hydraulic servovalve called Spacemaster is representative of advances made in miniaturization. Valve weighs 9.3 oz, is equipped with double filters, has good linearity and hysteresis.



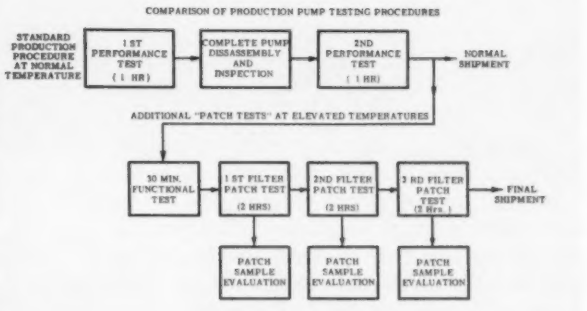
HIGH TEMPERATURE

High temperature hydraulic pump for X-15 is typical of advanced extreme-temperature components. Dual pump has —65 to 400°F capability. Uses MLO-8515 fluid.



RELIABILITY

Fig. 3. This flow chart illustrates the testing procedure for "clean pumps." See text for detailed description.


COMPARISON OF PRODUCTION PUMP TESTING PROCEDURES
STANDARD PRODUCTION PROCEDURE AT NORMAL TEMPERATURE
1 ST PERFORMANCE TEST (1 HR)
COMPLETE PUMP DISASSEMBLY AND INSPECTION
2ND PERFORMANCE TEST (1 HR)
NORMAL SHIPMENT
ADDITIONAL "PATCH TESTS" AT ELEVATED TEMPERATURES
30 MIN. FUNCTIONAL TEST
1 ST FILTER PATCH TEST (2 HRS)
2ND FILTER PATCH TEST (2 HRS)
3 RD FILTER PATCH TEST (2 Hrs.)
FINAL SHIPMENT
PATCH SAMPLE EVALUATION
PATCH SAMPLE EVALUATION
PATCH SAMPLE EVALUATION

The following advanced energy sources for hydraulic power have been investigated:

- Fly-wheel
- Solid propellant
- Primary and secondary batteries

For power transmission, both hydraulic oil and hot gases have been used. In certain advanced applications, it has been determined that the energy source most compatible with other system components is the primary battery. The dc electrical power from the batteries is converted to rotary motion by means of an electric motor, which in turn drives the hydraulic pump. Supplemental hydraulic equipment includes the reservoir, necessary valving, filters, etc. An hydraulic accumulator is often used to optimize the power output and minimize the energy demands imposed on the batteries.

The hydraulic power is then transmitted to servo actuators through normal hydraulic tubing. Each actuator unit is an integral package consisting of a feed-back potentiometer, a lightweight two-stage servo valve, and a rotary or linear actuator.

Component and System Reliability

Continued field reliability of equipment is another necessity.

Cleanliness of the hydraulic system has always been a must for optimum reliability. Each hydraulic component must receive attention in the development stage to determine how it is affected by contamination, and insure that the unit itself generates a minimum of contamination. One of the items that has had considerable development work in relation to this has been the hydraulic pump.

To produce a minimum contaminant pump, a program was first started on applications of supersonic aircraft and later successfully used on a number of missile applications, such as the recently phased out Regulus II.

To help secure this higher degree of cleanliness, some internal pump part changes are made. As an example, the antifriction bearing retainers are completely reworked to minimize sharp corners, surface roughnesses, and projections that do not affect bearing life or performance under normal conditions. The bearing manufacturers are now making special retainers to provide this ultra-clean construction. Ultrasonic cleaning is used on all major pump components.

Improved cleanliness of the entire unit is insured by a mechanical washing technique wherein the entire unit or its major components are attached to a reciprocating device that agitates the units in the solvent. Also used is a device that alternately applies pressure and vacuum to cored passages in castings to dislodge and remove contamination that may exist.

Filter Patch Test

Probably the most important single factor in this improved cleanliness program, determined by laboratory, production, and field tests is the filter patch test program. This procedure measures the amount of contamination generation occurring during normal pump operation.

Prior to actual filter patch testing, the standard test program is completed. This standard pump test consists of a one (1) hr performance test, a complete tear down and inspection, and a second one (1) hr performance test.

At this time, as shown in Fig. 3, the pump is then operated on a series of three, two-hour filter patch tests. After each two-hour test, the total contaminant from each 5 micron pump inlet, pump outlet, and pump case drain filters is collected and put upon a small patch.

Each two-hour contamination filter patch must show a smaller amount of contamination than the previous patch. A visual study, both with and without magnification, of the contaminant on these patches is made and the type of contaminant can usually be determined.

If a unit is rejected from any contaminant test, it is completely disassembled, inspected, and parts are replaced, as required. The unit is again subjected to a complete test program.

This has proved an extremely useful reliability tool and Chance Vought Aircraft has indicated that through the use of this process, the hydraulic system reliability has been increased by a large degree. This process is in use in approximately 10 applications and about 3000 pumps, meeting this stringent requirement, have been produced.

It is important to determine a pump's wear pattern during the 6 hr test. Experience indicates that a pump with an irregular wear pattern may show erratic contamination characteristics throughout its life. A pump breaking-in correctly will have a downward trend of contamination in each of the filter patch tests.

◆

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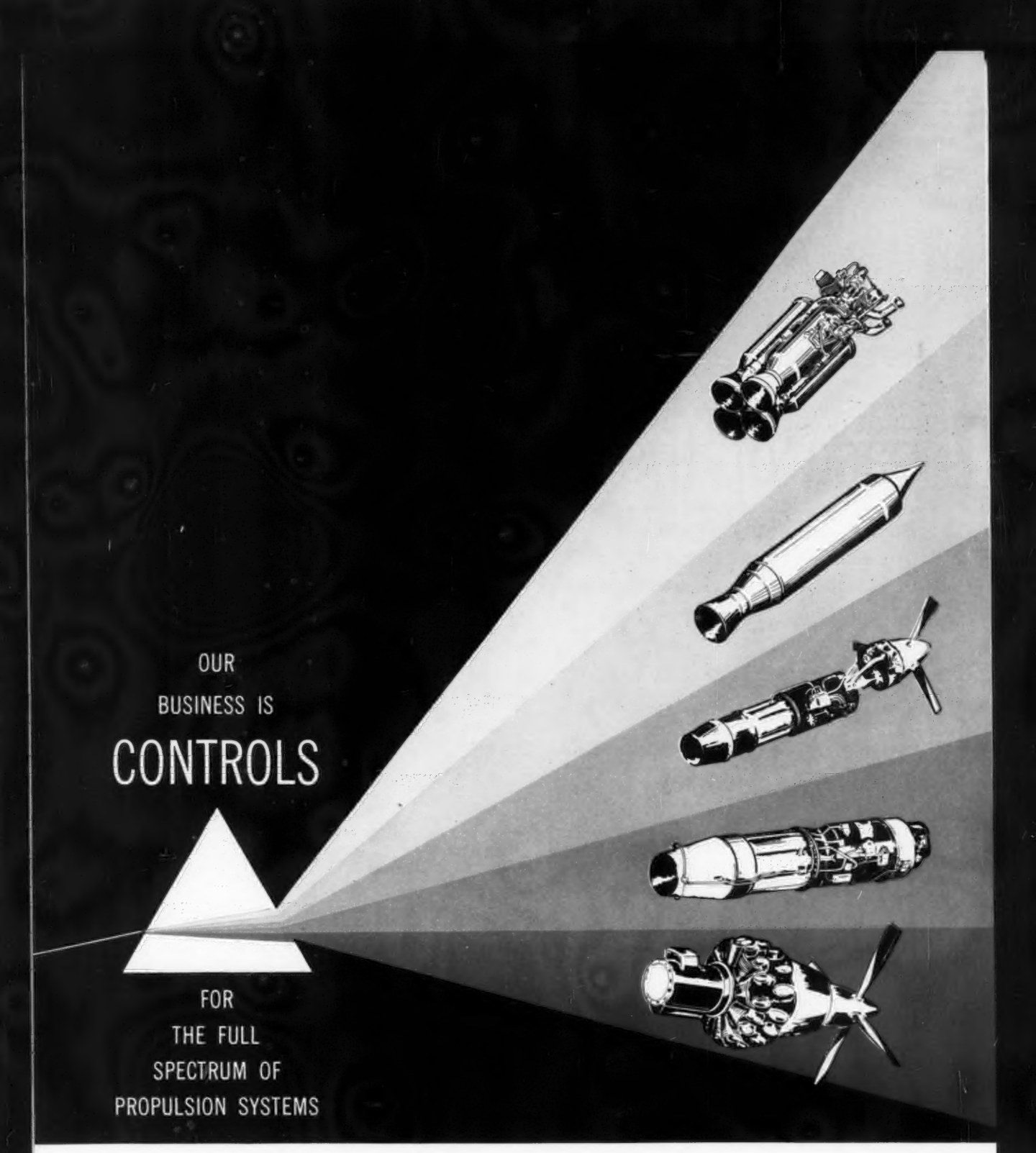

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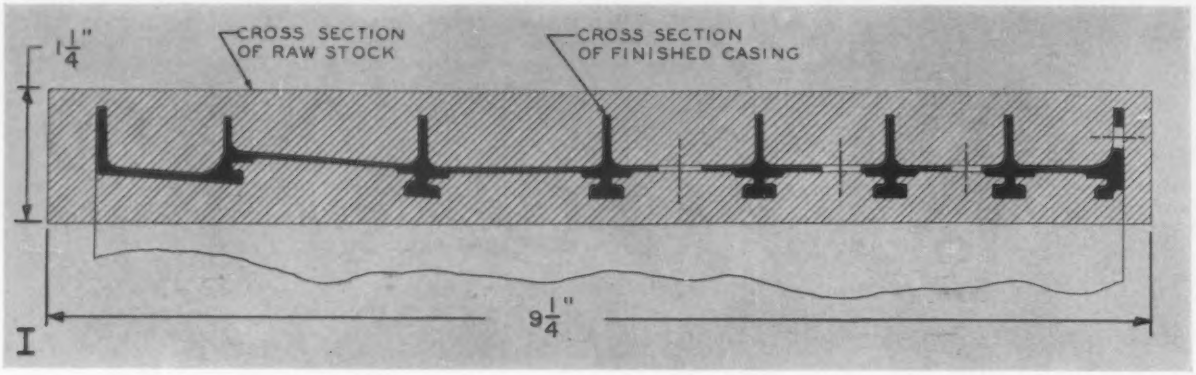
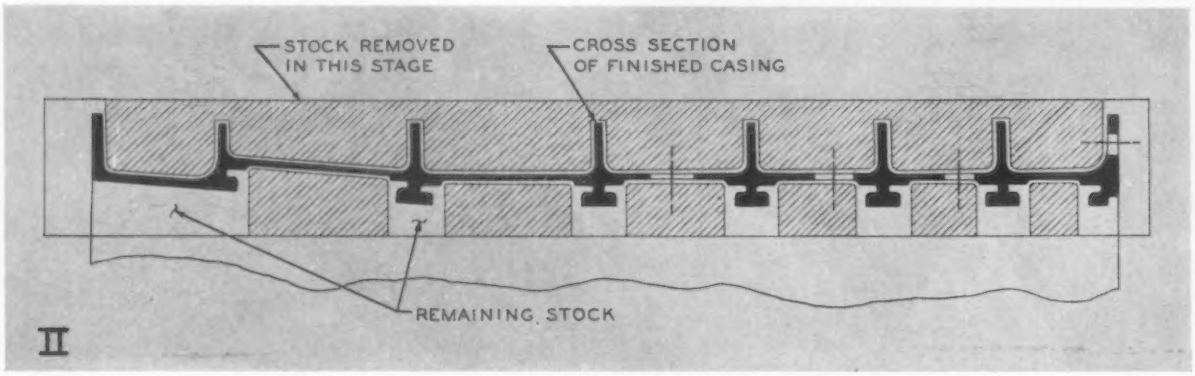


case of the J-85 compressor

Budd's metalworking skill produces intricate cross-section of GE designed, high thrust-to-weight jet

by S. Peter Karpielyan



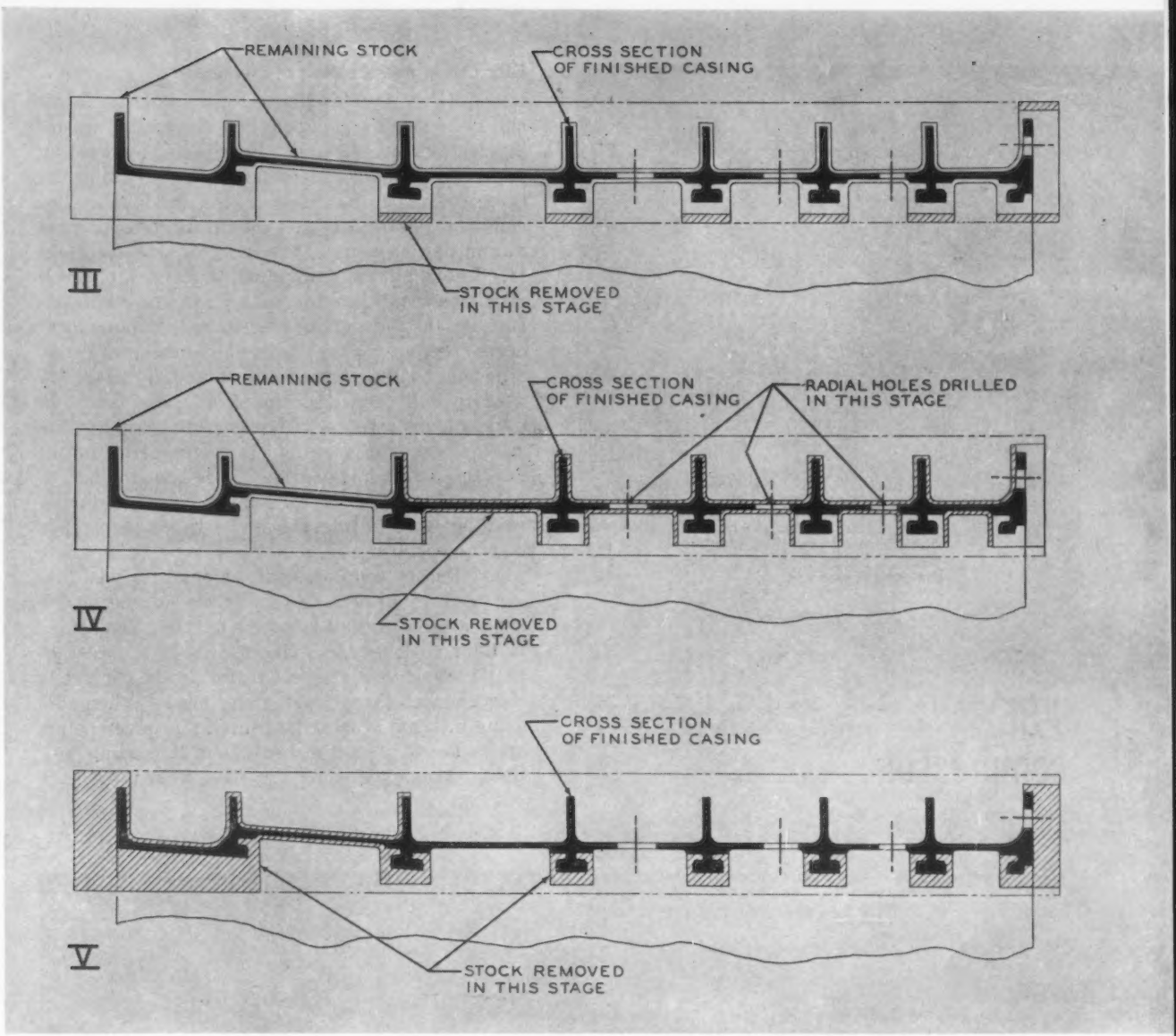
Comparative cross-sections of J85 compressor-casing blank and finished piece are shown in I, at top of this page.

Except for periods of hot wars the aircraft industry has been noted for its short-run schedules. This has stressed the need of flexibility in planning and the improvisation of economy tools. It has also brought out individual skill from the shadow of automation. The manufacturer of the compressor casing assembly for General Electric's J85 turbojet is a case in point. This casing assembly is built in the experimental production shop of Budd's Red Lion, Pa., plant.

Rough Machining of Casing Blanks

(Fig. 1) Two 80-lb, 1¼ x 9¼ x 28-in. Chromalloy-plate blanks are formed each into 180 deg semi-circles by power-braking every ½ in., then all machining and welding is done in accord with GE specs. Each half-blank is clamped horizontally in a G & L miller, and mating surfaces are rough-finished to provide a squaring plane for later operations. A 3/16-in. groove is cut along one edge of the mating surfaces, to facilitate joining; the two halves are welded together at the ends into a cylindrical blank by shielded arc. The cylinder is now annealed at 1750°F and cooled at the rate of 200° per hr.

(Fig. 2) The cylinder is then clamped in a 25-in. lathe with its previously finished edge adjacent to the chuck. The piece is checked for



Successive machining stages of the J85 compressor-casing cross-section are illustrated in steps II through V.

squareness, as well as soundness of weld, and preliminary machining is performed. Upon completion of the above, suitability for further machining is ascertained through ultrasonic inspection. The rough cross-sectional outline of the casing is now produced by machining off O.D. and I.D. material in a "T" lathe. End-flange regions of the case are machined last to allow chucking.

Next, the aft flange of the casing is rough-machined and more material is removed from the internal ribs. The casing is then clamped in a Sydney lathe from the opposite end; the wall thickness between ribs is finished from both within and without. The forward end flange is left heavy for subsequent chucking.

(Fig. 3) At this stage, a critical drilling process is used. Three adjacent rows of radial, bleed-holes are required through the wall of the casing. Each hole location must be within ± 0.005 in. from the parting plane between the casing halves. A radial drill and an indexing fixture are used for this purpose. After drilling and inspection, the welded case is split back into two halves. This is done by milling a $\frac{3}{8}$-in. cut along the original parting plane. This cut provides the lengthwise bolting flanges for final assembly.

continued on next page

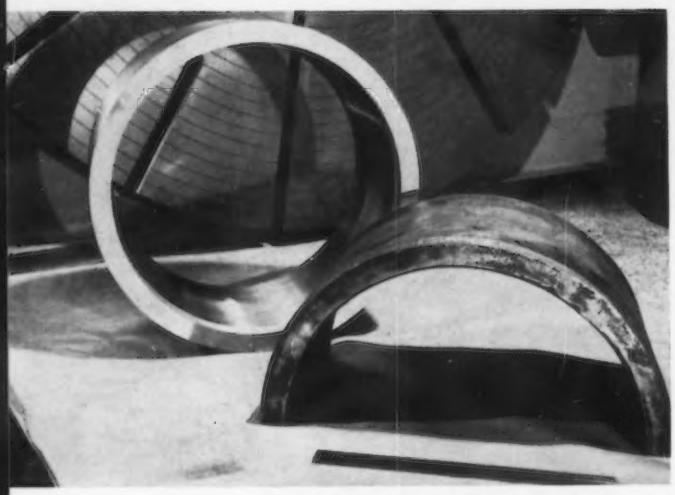


Fig. 1. Row stock of Chromalloy half-ring is shown in foreground. Two such halves are welded into a ring then machined. This ring, seen in background, is the basic blank for the compressor casing.

case of the J-85 compressor . . . continued

Fabrication and Welding of Elements

(Fig. 4) This phase consists of the fabrication of small components of the casing assembly. Individual pieces are then joined by welding to form an integral bleed manifold shrouding the three rows of radial holes drilled previously. The compact design of this manifold incorporates diminutive elements. Assembly of this manifold is effected by the individual tailoring approach of the most painstaking nature; welding is intricate because of confined areas and non-uniform cross section. Four externally-machined ribs, adjacent to the three rows of radial holes, are used to build the basic manifold. The manifold outlets are located near the parting plane; cross-sectional area of manifold is larger here than at 90° to parting plane where it is the smallest.

(Figs. 5 & 6) To combat warpage during welding, a rigid internal spider-brace, also made of Chromalloy, and a flat-bed type fixture are used. Before welding, with spider in a positioning fixture, adjustable extensions on the spider arms are set to the I.D. of the fixture. The spider is then removed and placed within the casing-half resting in a cradle fixture. Point contact is then checked throughout spider arms. When adequate internal bracing is insured the spider points are tacked to the unfinished I.D. of the casing half. Spider-arm extensions are now locked in place

Fig. 3. Three adjacent rows of radial bleed-holes are drilled. Each hole is within ±0.005 in. from parting plane between casing halves.

Fig. 2. Preliminary machining generates rough outline of casing cross-section.

by tightening of backup nuts. At this stage, the casing is ready for welding. In areas where external clamping is not practicable, removable, internal positioning-spacers are also used; the pieces to be welded are secured in place by intermittent tack-welding; the positioning spacers are then removed, and the final welding is accomplished. Welding progresses at the rate of only a few inches at a time. The reason for this is that Chromalloy is readily susceptible to surface corrosion. Therefore, the area to be welded is cleaned with a stainless brush immediately before welding. To prevent regional distortion care must also be taken not to overheat the casing through prolonged welding. Horizontal bolting flanges are welded first while casing and spider are kept within a holding fixture. The flanges are X-rayed upon cooling. Casing-half and spider are then stress-relieved together by heating to 1125°F for one hour, followed by furnace cooling. To check the results at this stage, Zyglo inspection is used. Faces of horizontal flanges are now rough-finished to within 0.060 in. of final dimensions. Next, crescent-shaped extensions are welded on the external ribs, then Zyglo inspected. Assembly of integral manifold progresses by hand fitting each successive component, tacking, filing off excess weld, and inspecting. The finished manifold is tested for leaks by internal

Fig. 4. Components displayed in front of casing half will be welded into an integral bleed-manifold and shroud the radial holes.

Fig. 6. Welding of casing progresses a few inches at a time. Areas to be welded are brushed meticulously right before welding.

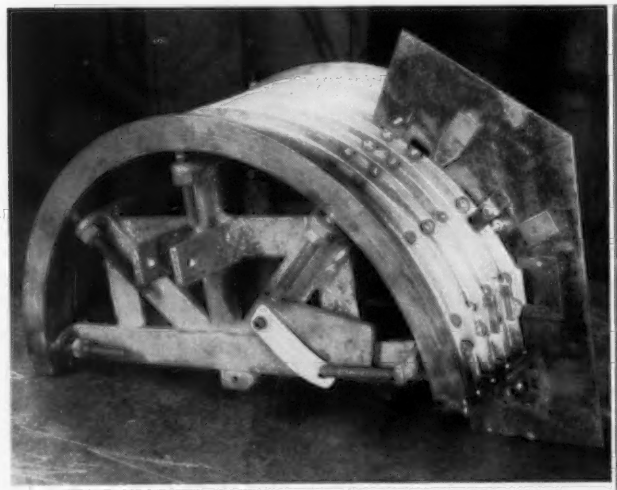


Fig. 5. Rigid internal spider prevents casing warpage during welding sequence. Plate fixture at right holds crescent-shaped rib extension plates in place for initial tacking.

case of the J-85 compressor . . . continued

Fig. 7. Upon completion of welding the spider fixture is removed and casing-half mating surfaces are finished. Here, the flange bolt-holes are being drilled.

pressurization and application of a bubbling compound. The completed casing-half and spider unit is then heat-treated. The unit is hardened first by slow heating to 1750°F, then forced-air cooled, and tempered at 1200°F from two to three hr. Throughout heat-treat, a test coupon from the original stock accompanies the casing. The spider brace has now served its purpose; it is severed from casing-half at the tacked areas. The casing is then checked for squareness.

Final Machining Sequence

At this stage the mating surfaces of casing-half lateral flanges are machined to final size. This operation is critical because it has to re-establish the ±0.005-in. tolerance of the radial holes. This tolerance was first established while casing-halves were in a joined condition.

(Fig. 7) The lateral flange surfaces are finished in a fixture. This is followed by drilling, reaming, and counterboring of flange bolt-holes.

(Fig. 8) The two casing-halves are now reassembled by bolting through the lateral flanges; the casing assembly is chucked in a lathe from its forward end; and accessible compressor-blade slots are cut. The casing assembly is then chucked from its aft end to finish remaining blade-slots and the tapered I.D.

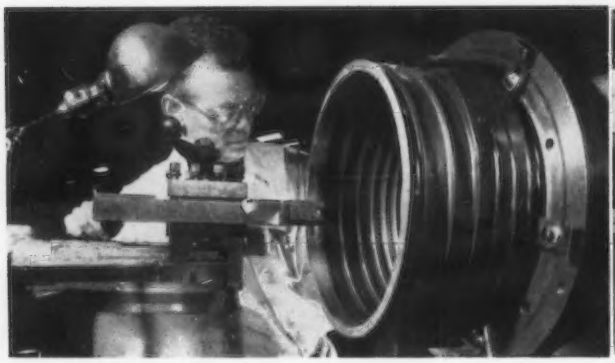


Fig. 8. Final machining of I.D. is performed after assembly of casing halves.

Fig. 9. Bleed-manifold mounting-pad surfaces are milled, then lapped to 0.001-in. flatness.

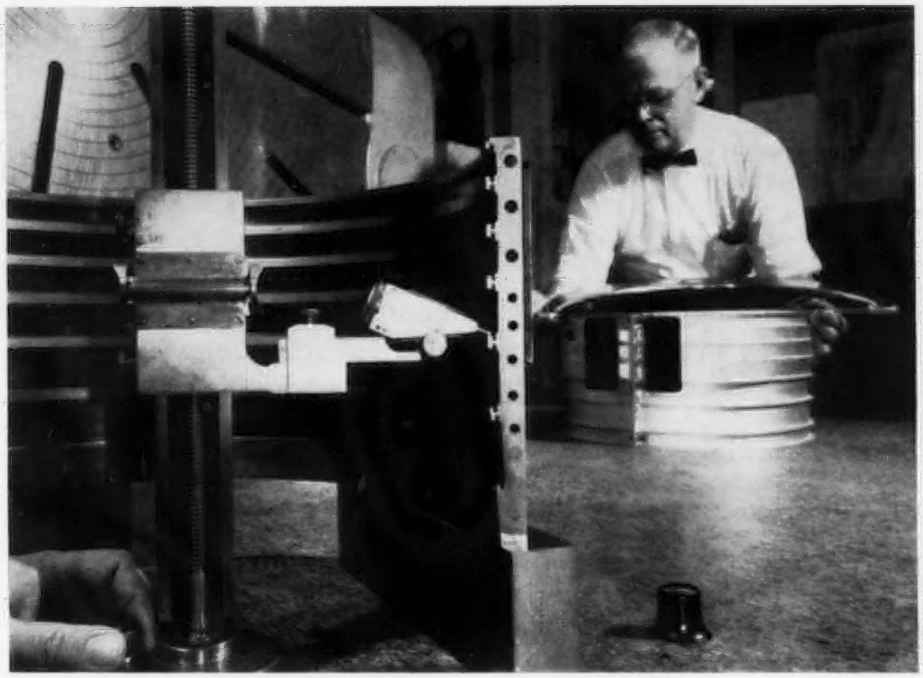


Fig. 10. View of inspection operations highlights cross section of casing half at the mating flange. Fully assembled casing can be seen at right.

(Fig. 9) In the next sequence, the manifold mounting-pad surfaces are set up, milled, and lapped to 0.001-in. flatness; the smaller oval pad is also milled. Holes on both bront and aft casing-flanges and pads are now drilled in a radial drill. Inaccessible holes are spot-faced backward.

(Fig. 10) Upon final machining, the casing assembly is disassembled, deburred, cleaned, and inspected thoroughly.

The machined surfaces are presently masked and the halves are aluminum-oxide blasted, then coated by silicone paint for protection. After air-drying first coat for 30 minutes, a second is applied and baked at 285°F for two hr. After a final inspection, the casing is reassembled and shipped to GE, with test coupon and metallurgical data. The weight of the finished casing assembly is about 18 lb. The manufacturing sequence of this unit may appear as anachronous with the very age of speed it promotes. It is so because it depends more upon conscientious workmanship and resourcefulness than on highly specialized equipment. The very low scrappage-rate thus far can well bear out this point.

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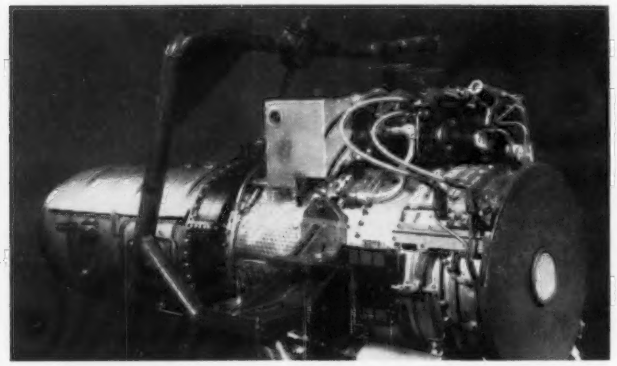

The 2000-lb thrust J85 is produced by General Electric's Small Aircraft Engine Dept., Lynn, Mass.

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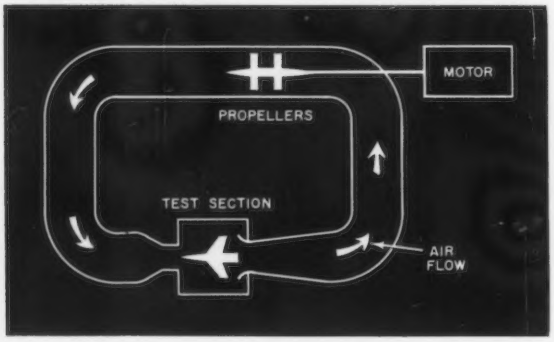
limitations in design evaluation

inability of test equipment to simulate all high-speed environments puts question mark on some preflight data

by **Armin Bruining**, Marine, Transportation, and Aviation Facilities, Westinghouse Electric Corp.

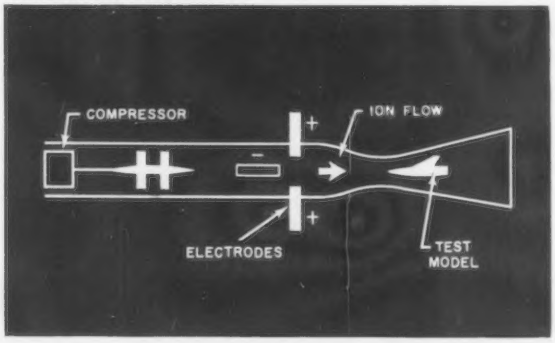
Many tests have been developed to determine the fatigue resistance of metals, and limitations of equipment at elevated temperatures. All are lacking in some respect. Even in-flight temperature tests of completed missiles are somewhat unsatisfactory because of the difficulty in gathering data and recovering the missile. Scale-model tests cannot be extrapolated with any degree of accuracy because the scale factors for stress, temperature, diffusion, and aerodynamic characteristics all have different relationships to the mass and size of the missile or plane.

Continuous-Flow Tunnel



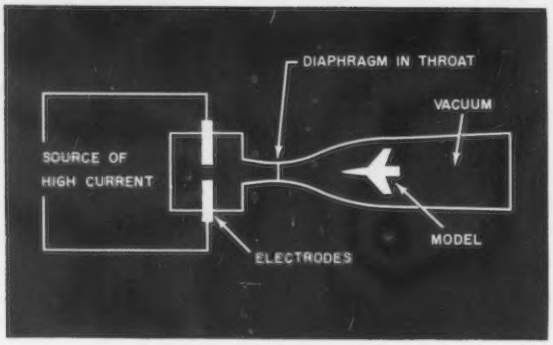
Ideally, ground testing can be accomplished by subjecting a model or airframe section to wind-tunnel tests where the air velocity, density and temperature are equivalent to actual flight. However, the first major obstacle is cost; the cost of making a tunnel capable of producing air velocities equal to those encountered by missiles. Second obstacle is that the airflow which simulates temperatures of high-speed flight creates a problem of cooling the walls, nozzle, and compressor of the wind tunnel. At present, most tunnels in daily use are limited to temperatures of 1500°F. Experimental tunnels have been built that can operate with stagnation temperatures of nearly 5000°F. Because of temperature limitations, the continuous-flow tunnel can only pump air, with the correct Reynolds number and enthalpy, up to about Mach 7.

Electric-Arc Tunnel



To circumvent these problems, several alternative test methods are used. The simplest is to heat a model in an electric-arc tunnel. In this method, an electric discharge between two electrodes creates air temperatures in the range of 100,000°F. A compressor then blows the heated air over the model. At this temperature, the air becomes highly ionized, and, as a result, the test does not accurately simulate actual in-flight heat-transfer mechanisms, structural loading, or chemistry of the air in contact with the specimen. Air speeds are limited to Mach 1 with present designs.

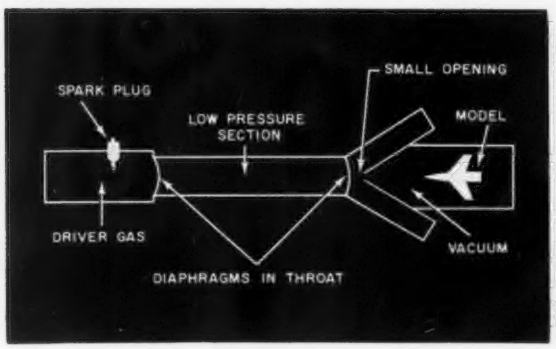
Hot-Shot Tunnel



In the Mach 10 range, with densities representative of high altitudes, tunnels employing short time air flows are most used. These "hotshot" tunnels, while they can produce a realistic airflow at 10,000 to 15,000°F for 10 to 15 milliseconds require extremely refined instrumentation. Also, the desired flight conditions cannot be programmed into the test equipment.

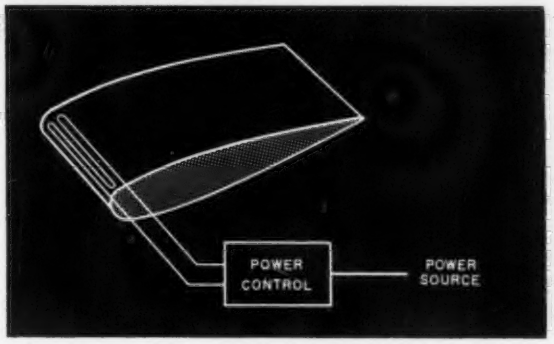
Another limitation inherent in the hot-shot tunnel arises from the basic definition of temperature. Temperature is a parameter that indicates amount of energy contained in a material. This energy affects mechanical characteristics of the material and the ability of the material to transfer its energy. The energy can exist by virtue of different mechanisms: Translation, vibration, spin or rotation of the molecules; ionization of the molecules into atoms; exictation of atomic electrons; and free electrons in vibration and spin liberated from the atoms. Under normal conditions, these energy states are in equilibrium, so that, measurement of radiant energy, directly related to the electron energy of the atoms, also gives a measure of the other energies. Unfortunately, for a certain set of conditions, each of the mechanisms requires a certain time to absorb or dispense its energy. Hot-shot testing techniques are hard to interpret because, lasting only a few milliseconds, these mechanisms of energy storage are not in equilibrium, as they would be in actual flight.

Shock Tube



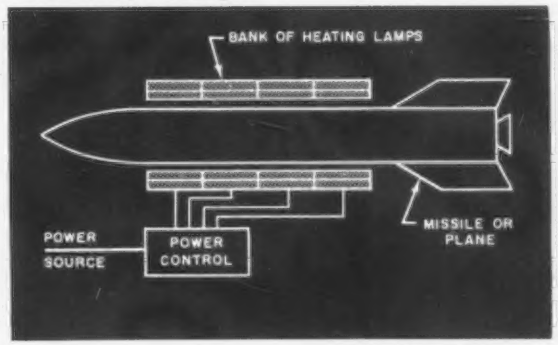
In another short time test, "the shock tube," a supersonic wave front is generated through the gas by an explosive driving mechanism. By using rapid repetitive cycles, fairly long test periods can be obtained. These allow the use of low enthalphy, i.e., the amount of heat per unit mass is low. Here, as in all air flow techniques, helium is usually used above Mach 7 to prevent the gas from liquefying after exit from the supersonic nozzle. Using helium, speeds up to Mach 50 can be produced. This method, as does the hot-shot tunnel, suffers from the variation of energy distribution in the wave front.

Radio-Frequency Heating



Radio-frequency induction heating is capable of producing heat fluxed high enough to simulate heat generated during the re-entry of missiles. Induction coils set up currents in the metal to produce the heating required. Banks of these coils can be arranged to test a complete missile, and with separate control channels, different areas of the missile can be subjected to different temperatures. The tremendous amounts of electrical energy required for this type of heating, however, usually prevents the entire missile from being heated at one time. A serious disadvantage is that different materials heat at different rates, due to differences in electromagnetic permeability, thereby giving thermal gradients that do not duplicate aerodynamic heating. Accurate simulation of aerodynamic forces is also difficult.

Radiant-Lamp Heating



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limitations in design evaluation . . . continued

Electronic and air-conditioning equipment can be simply tested by placing a section of the airframe in a pressure vessel and reducing the pressure to correspond to the desired altitude. Banks of tungsten - filament, quartz - enclosed lamps, then maintain desired temperatures on various areas of the plane or missile. Power levels to the lamps are controlled with temperature controllers in conjunction with ignitron-contactor power controls. This system cannot develop heat fluxes high enough to simulate reentry of missiles. It can be used, however, to test some interesting portions of the flight of intermediate-range and intercontinental ballistic missiles.

Before making such tests, either the structure-temperature or aerodynamic heat-transfer characteristic must be predictable over the entire vehicle. Because these are ground tests, the aerodynamic and "g" loadings must be simulated by a point wise approximation, such as by pulling on the structure with piano wires. The mechanisms of heat transfer in such tests are radically different from those in actual flight.

However, of all high temperature test facilities, the "hot body" or radiant lamp technique is most used. In this method, the heating lamps can be controlled to accurately reproduce the temperature rise encountered in the transients of actual flight. The temperature can be made to rise at 1000 to 3000°F/sec. Since full-scale missiles or planes can be tested in this method, different designs can be directly compared without any scale factors. Also, the radiant lamp technique is relatively simple and inexpensive to use.

Test Program

Two approaches are made in controlling the radiant lamps to simulate the temperature rise encountered by a missile. The simplest, from the equipment standpoint, utilizes a precalculated curve of skin temperature versus time. The skin-temperature signal, after comparison with a feed back signal indicating the actual temperature of the missile, is used to regulate the system. This type of control is hard to apply, in that it presupposes the temperature of the missile skin (T_s) as a function of time.

The skin temperature must be calculated from the heat equation, but because of the complexity of aerodynamic heating, radiant cooling, and internal structure cooling, an analytical solution is difficult to obtain. In addition to the analytical difficulties, the physical constants such as conduction across metal-to-metal joints are highly variable and difficult to ascertain.

The other approach uses a heat signal representing the net heat influx through the skin to control the power level of the lamps. This signal is equal to the heat absorbed from the air boundary minus the heat radiated by the skin, as expressed in the following equation:

$$Q = h(T_e - T_s) - E\,kT_s^4$$

where h = the heat-transfer coefficient, T_e = the effective temperature of the air boundary, T_s the skin temperature, E = the emissivity of the skin, and k = the Stephan Boltzmann constant.

The value of Q is continuously calculated in a computer during the test and used to control the power level of the radiant lamps.

To assure that the actual value of heat entering the skin is equal to the calculated value a feedback loop is inserted. A measure of the actual heat applied is obtained by two methods. The first uses a correlation factor between the electrical energy applied to the lamps and the heat entering the skin surface. This correlation, or efficiency factor, is difficult to determine. In the second method, the net heat influx is found by taking the derivative of the skin temperature signal (T_s).

While the missile is run through a temperature test, mechanical loads are simultaneously applied to simulate aero-dynamic forces. The stresses set up in the skin and structure are then recorded. This gives a fairly accurate idea of how the structure will withstand the shock of thermal and aerodynamic loads in actual flight.

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Shown is the Talon T-38 trainer, developed in parallel with the new N-156F supersonic jet fighter by Norair, a division of the Northrop Corporation. When the N-156F comes off the production line, it will carry Chatham power supply 28VS100BL-1—a 100 amp, blast-cooled, silicon unit especially designed to Northrop specifications.

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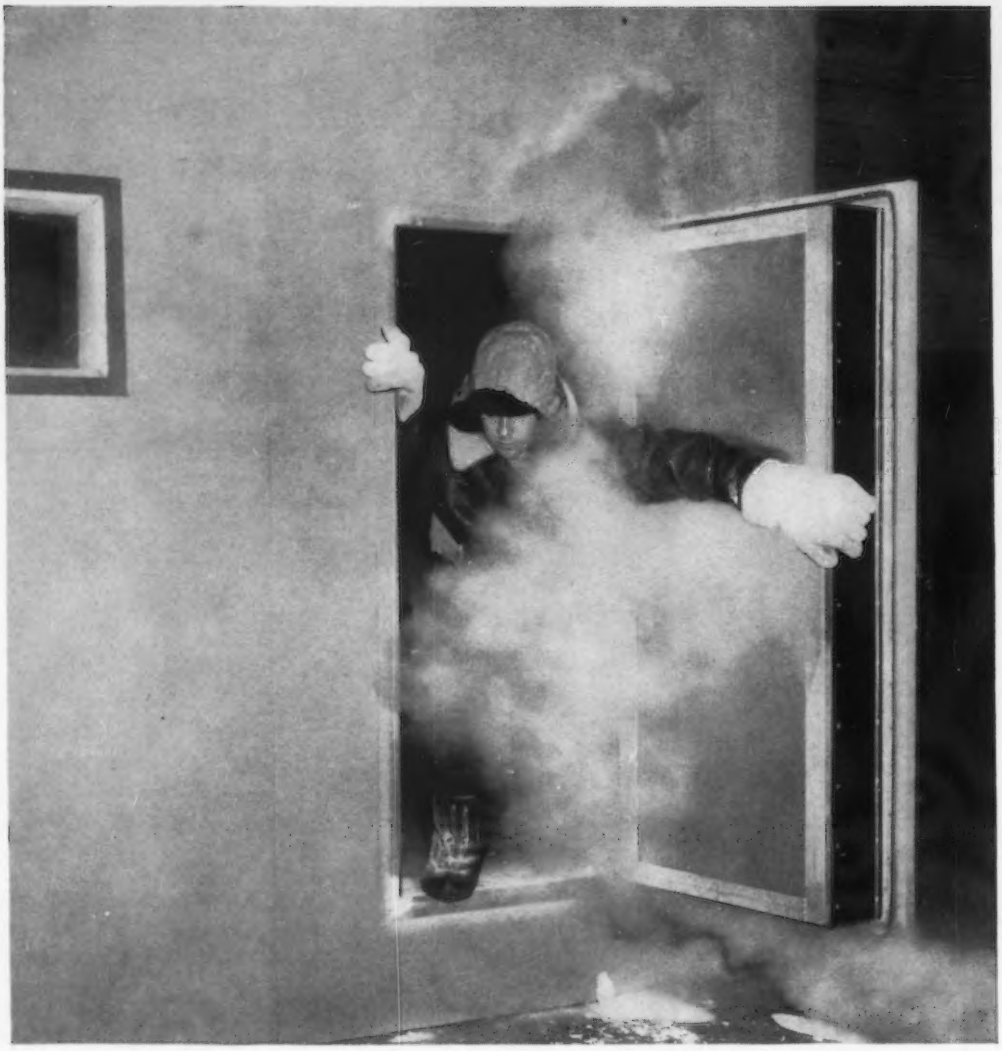

Partial view of a 10′ x 10′ x 35′ low temperature test chamber built by the Mantec Division of Wyle Manufacturing Corp., El Segundo, California. Bulk liquid PURECO CO_2 can bring the interior down to —110° F. in minutes.

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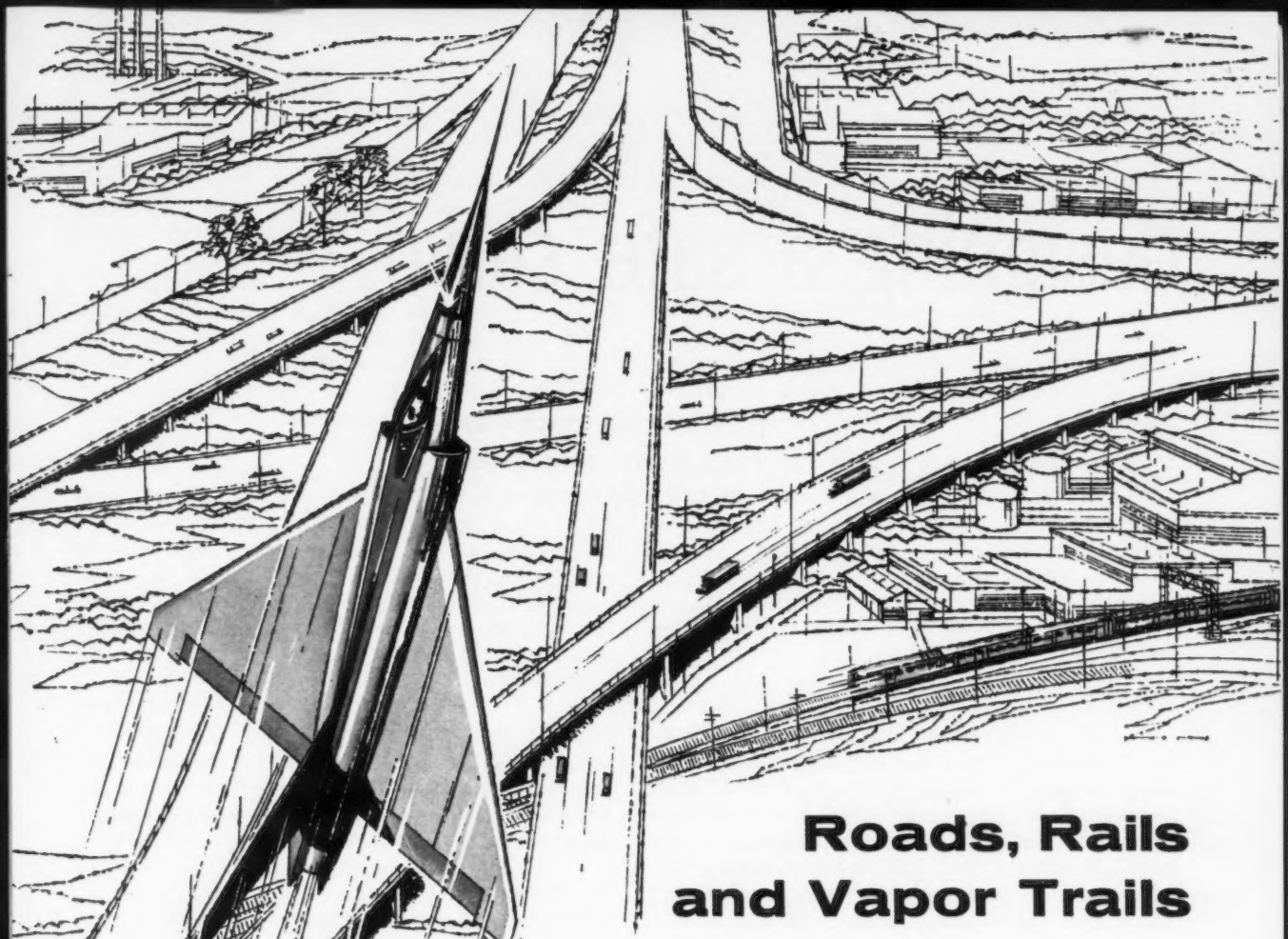

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designing a safe servo

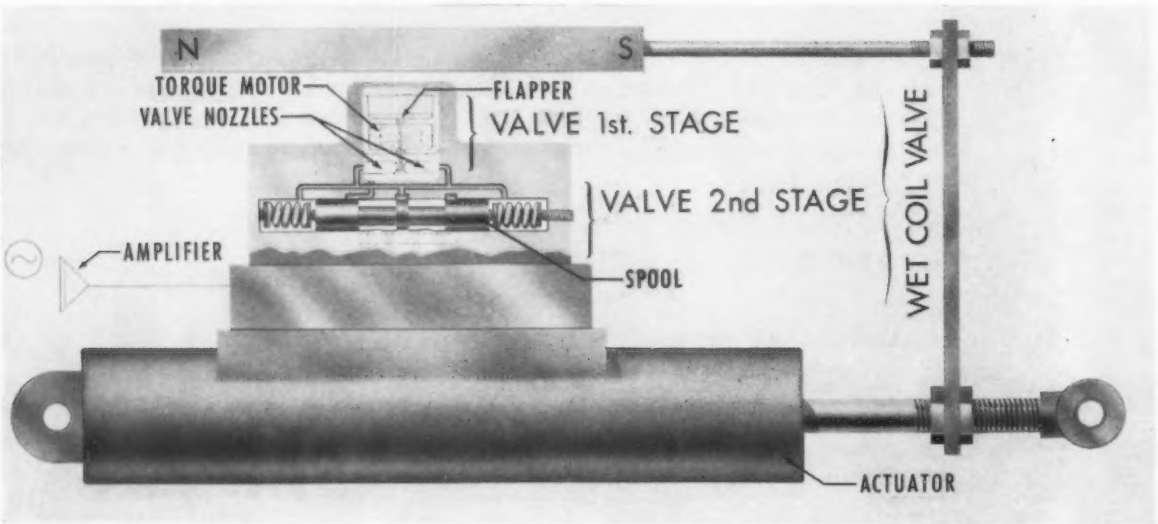
magnetically-positioned electro-hydraulic servo has failsafe feedback-loop

By **Robert Hayos**, senior engineer, flight control systems, Nortronics Div., Northrop Aircraft Inc.

The role of the closed-loop servomechanism has been gaining increasing proportions in the development of new aircraft components and systems. In recent years the electro-hydraulic proportional transfer valve has been incorporated in many off-the-shelf items. The majority of these valves utilize a two-stage design in which the torque motor serves as a first stage; the hydraulic amplifier as the second. However, many variations in the method of control are employed, such as pressure control, flow control, acceleration switching and other refinements. This article is limited to studies made with the more common types of flow control units.

A limitation of most existing electro-hydraulic transfer valves is their inability to maintain a stable hydraulic neutral position when operated under open-loop servo conditions. Consequently, loss of feedback signal to the servo results in a movement to the "hard-over" condition.

Fig. 1. Permanent Alnico magnet is positioned close to the valve flapper end by mechanical linkage with hydraulic ram.



Even in the limited authority applications of the "typical" aircraft stability augmenter type servo, a hard-over failure can mean grossly limited performance and possibly an aborted mission.

The flow-control valve utilizes the principle of producing a flow of fluid, to an output port, directly proportional to a current flow in the valve's torque-motor coil. In the conventional four-way transfer valve, a reversal of coil current results in a reversal of the valve-spool position. This corresponds with a reversal in the oil flow through the valve output ports. The design of the torque motor is such that the magnetic flux distribution, about the coil, is carefully controlled to give an even flow in both directions. Early experiments in attempting to modify the flux distribution, by external magnetic influences, resulted in greatly changed flow characteristics. It was found that by introducing a permanent magnet into the magnetic field of the torque motor coil, a complete cessation or even reversal of flow could be induced, irrespective of input current; also, that a more pronounced effect could be obtained by bringing the magnet as close to the valve flapper member as possible. Such effects are utilized to act as positioning forces in a closed loop electro-hydraulic control system.

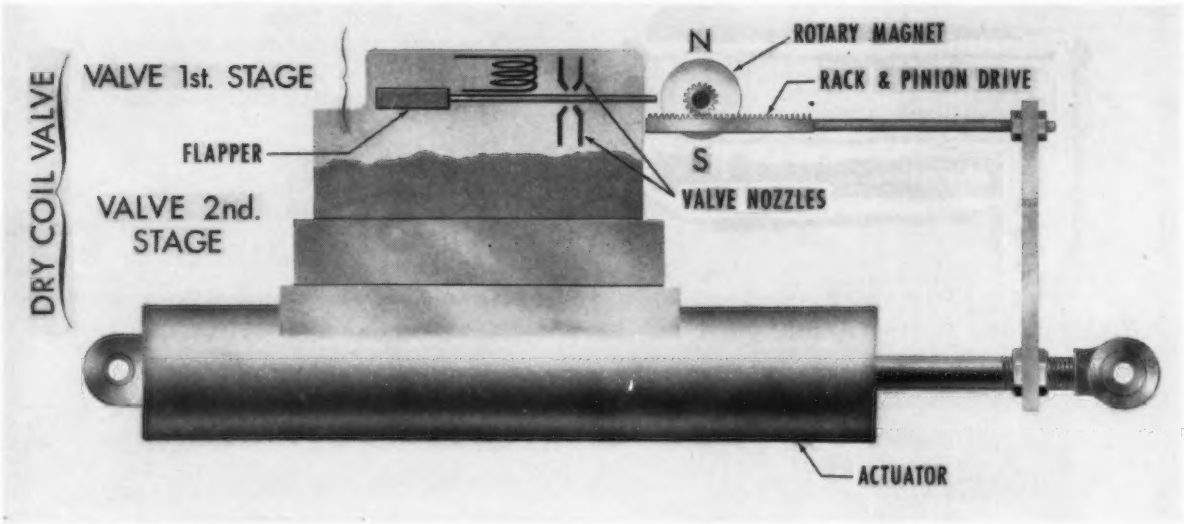
Fig. 1 shows a permanent Alnico magnet positioned close to the valve flapper end by mechanical linkage with the hydraulic ram. As a signal is transmitted to the valve coil, normal valve operation proceeds with a resultant motion of the hydraulic actuator piston. The mechanical link transfers this motion back to the magnet; this results in an opposite polarity to that induced into the valve coil over the wand. This force then acts to nullify the electro-magnetic forces, and all further motion of the servo ceases.

Because of the nature of typical potentiometer design, this element has certain inherent weaknesses which makes its elimination highly desirable. In a flight-control system the typical potentiometer used as a feedback element has a resistance in the order of 10,000-30,000 ohms. This calls for wire diameters of 1.0 mil and less to obtain the desired resolution characteristics. Such fine wire, when wound into coils, is subject to easy breakage. In addition, the wiper within the potentiometer, relying on high contact pressures, offers another source of failure.

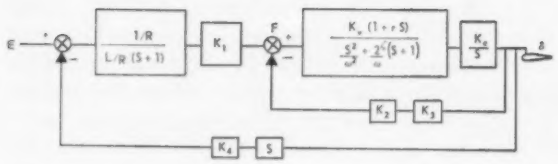
It was also found that unlike the conventional servo, which would drift to a "hard-over" position upon loss of feedback signal, the servo arrangement with a permanent magnet would immediately position to a central or neutral position. This "failsafe" characteristic results from a tendency of the magnet (with its equally permanent poles) to center over the flapper. In the conventional servo a loss of feedback results in an open feedback loop. However, as shown in Fig. 1, the loop is closed in this case—not around the entire servo—but, about the highly critical valve element. The force balance on the flapper thus becomes the summing point of the servo loop.

continued on next page

Fig. 2. Round rotor magnet shown has traverse polarization, with poles positioned diametrically opposed.



SYSTEM BLOCK DIAGRAM



Transfer Function of Forward Position Loop

$$\frac{\delta}{F} = \frac{G}{1 + GH}$$

Where G = transfer function of forward elements
H = transfer function of feedback elements

$$\text{and} \quad \frac{\delta}{F} = \frac{\left[\frac{K_v(1+\tau S)}{\frac{S^2}{\omega^2}+\frac{2\zeta}{\omega}(S+1)}\right]\frac{K_c}{S}}{1+\left[\frac{K_v(1+\tau S)}{\frac{S^2}{\omega^2}+\frac{2\zeta}{\omega}(S+1)}\right]\frac{K_c K_2 K_3}{S}}$$

simplifying

$$= \frac{1}{\frac{1}{\left[\frac{K_v(1+\tau S)}{\frac{S^2}{\omega^2}+\frac{2\zeta}{\omega}(S+1)}\right]\frac{K_c}{S}} + K_2 K_3}$$

Transfer Function of the Outer Rate Loop Includes the Above Position Loop

$$\frac{\delta}{E} = \frac{G}{1+GH}$$

$$\frac{\delta}{E} = \frac{K_1\left(\frac{\delta}{F}\right)\left[\frac{1}{L(S+1)}\right]}{1+K_1 K_4\left(\frac{\delta}{F}\right)\left[\frac{1}{L(S+1)}\right]S}$$

Where:
- R = Coil resistance of valve
- K_v = Overall valve gain/K
- K_c = Cylinder gain
- T = Time constant valve
- ω = Undamped natural frequency
- δ = Servo actuator displacement

Mechanizing this new system was the next problem to be considered. Initial mechanization used a simple bar magnet positioned transversely over the valve coil. However, low quiescent permeability of this magnet excluded this configuration. Instead, the round rotor type of Alnico 5 magnet was evaluated (Fig. 2) ; tests showed that by properly orienting the magnetization flux path a relatively high permeance level could be obtained. Such magnets are conventionally polarized axially, with a pole on either surface. This application however called for a transverse polarization, with the poles positioned diametrically opposed. With this arrangement an equal flux distribution is obtained, resulting in excellent zero positioning. The rotary magnet is so located that it is driven directly in front of a small extension to the valve flapper. At neutral position the poles are equidistant from the flapper; as the magnet is rotated, by the mechanical drive from the piston arm, either the north or the south pole is brought closer to the flapper. As this occurs, the corresponding force begins to counteract the opposite polarity effect within the valve coil. This flux is then the effective feedback force and results directly in the positioning of the valve.

The entire magnet assembly, together with its drive "gearing" and housing, is fitted as a direct attachment over the valve's torque motor and actually replaces the torque motor cover. An adjustment is provided to enable the magnet to be positioned at a finite distance from the flapper. This latter feature is important because the gains obtained from this system decrease as the square of this distance.

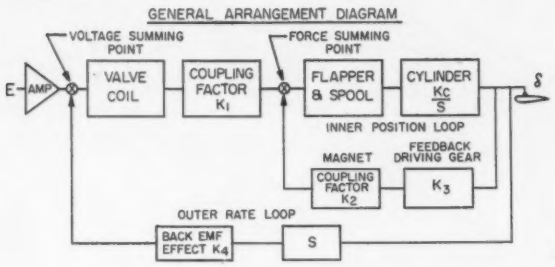
Another important design consideration was the use of tight mechanical coupling, to eliminate all backlash. With the arrangement shown in Fig. 2, the magnet was driven by a conventional rack and pinion drive.

Frequency response measurements were all conducted at a 0.02-in. total displacement in order to study amplitude ratios and phase lags to the

- E = Input command voltage
- F = Force summing point
- K_1 = Coupling factor relating force on valve flapper to coil current
- K_2 = Coupling factor relating force on valve flapper to feedback magnet rotation
- K_3 = Coupling factor: Feedback linkage and magnet driving gear
- K_4 = Coupling factor: Back EMF effect of magnet
- S = Laplacian operator
- ζ = Damping ratio
- F = Force summing junction

upper limit of the frequency of interest. Since the particular servo under evaluation was of the low-velocity-low-frequency type, it was unnecessary to strive for high dynamic response. It is entirely possible that good dynamic performance might be obtained at frequencies well above those investigated.

Analysis



The above diagram represents the arrangement of the magnetically-positioned servo showing the two feedback loops. The inner or position loop represents a feedback network about the cylinder, the valve flapper, and the spool. The forces caused by the valve coil, on the flapper, and the magnetic flux of the rotary magnet are vectored at the "force summing point."

The outer or rate loop is the other feedback network and together with the output of the summing amplifier represents a voltage summation. This loop is a result of the velocity effects of the feedback magnet.

The transfer functions for these two loops are shown as follows:

Application

The prime aircraft applications of the foregoing principle is in small-amplitude stability-augmenter-type servos. Although such applications are generally for higher response systems than have been laboratory tested, it is felt that they are most certainly within the realm of possibility. This method of control could also be applied to prime surface actuators and other typical servo-controlled devices.

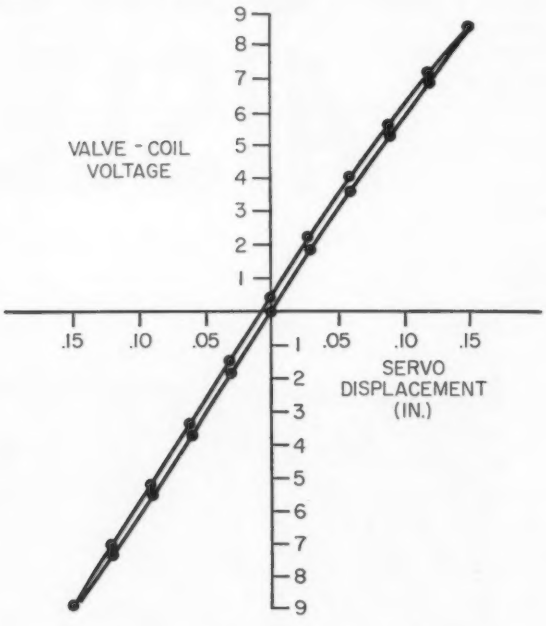
What to look for in Electro-Hydraulic Servo Valves
B. A. Johnson, L. D. Schmid and J. Warshowsky Control Engineering June 1956

A Hydraulic Servo with Magnetically Coupled Feedback
S. A. Myers and L. N. Tanner Northrop Report NAI 55-574 June 1955

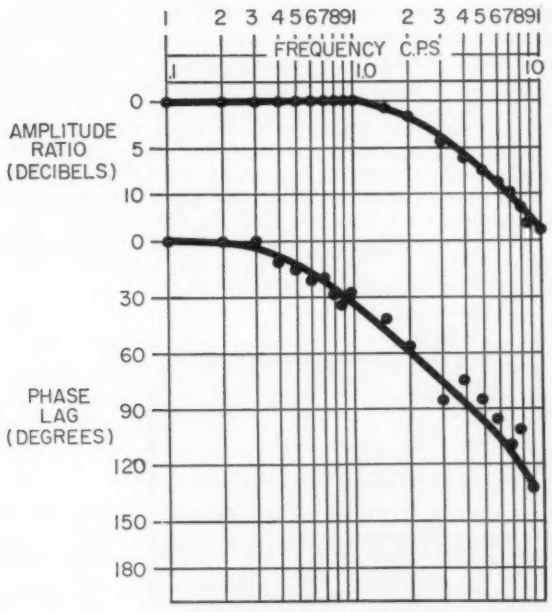
Magnetic Feedback and Non-Linear Valve Techniques Applied to Electro-Hydraulic Servos
S. A. Myers Northrop Report MD 56-32 Feb. 1956

A Magnetically Positioned Electro-Hydraulic Rudder Trim-Servo
R. Hayos and G. R. Mills Northrop Report NAI 57-698 June 1957

Linearity-hysteresis diagram shows near-linear response obtained with magnetically-positioned electro-hydraulic servo.



Frequency-response diagram of typical magnetically-positioned electro-hydraulic servo.



For the savings in tool costs made by Hydroforming

Col. Herman E. Lacy calls this his

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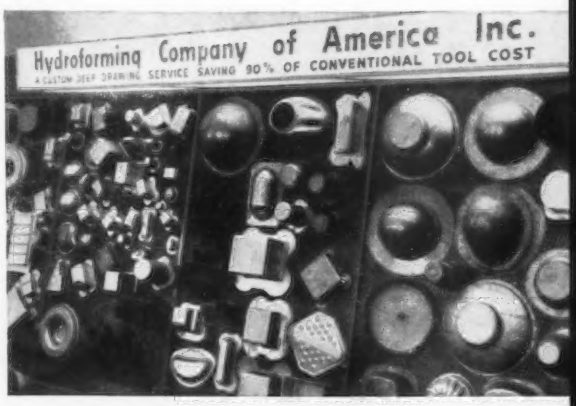


This photo of a display panel at Hydroforming Company of America, Inc., shows the wide range of Hydroformed part size, gage and complexity of shape produced by this firm.

Three key members of MIT's Servomechanisms Lab discuss APT language. Prof. J. F. Reintjes, standing at left, is director of the lab; behind him, D. Clements, project engineer; and D. T. Ross, at right, head of the lab's computer applications group.

Automatically Programmed Tools

commands in abbreviated English simplify programming of numerically-controlled machines

Communication between man and machines is reaching a new phase. Verbal commands in pseudo-English can now be used to direct numerically-controlled machine tools. Since the vocabulary used is basically an abbreviated form of English, it is simple to learn and to use. This is the result of the APT-II Phase I (Automatically Programmed Tool) project—an outcome of numerical control studies at the MIT Servomechanisms Lab begun in 1956, under the leadership of D. T. Ross of MIT.

The APT project has involved the combined efforts of Aircraft Industries Association members, and MIT under Air Material Command sponsorship. The science of numerical control is presently in its infancy, and APT is the first step in a continuing effort to optimize this science by pooling resources; this program is open on a mutual support basis, to all organizations interested in numerical control.

Essence of Numerical Control

Basically, this process consists of controlling the cutting tool of a high-precision machine, such as a contour mill, through series of numerically coded instructions. The machine responds to signals fed to its sensing and control circuits by the "director." The director reads the numerical instructions (in punched-tape form) and translates them into machine-tool commands.

The input language usually consists of one number for each controlled axis of motion in the machine tool, and another number representing time. The director commands the cutter to move in the specified time interval, along some simple curve, usually a straight line, from its present location to a new point. Thus the cutting tool is "programmed" to follow a complex broken-line path. Intricate three-dimensional surfaces are generated, within specified tolerances, by approximating with successive elementary machine tool motions.

Slowest Link in Process

The slowest link within the numerical control process thus far has been the tedious process of "manual part programming." In this step each cut vector or tool-center location is calculated manually, using a desk calculator; the results are tabulated on a process sheet. In addition to the problem of approximating curves by straight lines, another consideration makes manual programming a slow and difficult process while the director controls the central reference point of a tool, it is the cutting edge of the tool which produces the finished surface.

Development of APT-II Phase I System

In the period of 1950 to 1955 the MIT Servomechanisms Lab, under Air Material Command sponsorship, developed and tested the first numerically-controlled milling machine. During this development the need for an industry-wide APT System with a readily understandable programming language was determined. Accordingly, computer programming manpower and resources were pooled to produce a flexible APT system for the aircraft industry. Since interested companies either had or planned to have a general purpose IBM 704 computer, it was decided to

← Circle 11 on Inquiry Card, page 83

code the system for this computer. Among the growing number of numerical-control director-systems, each has its own form of numerically-coded input-language and related peculiarities. The philosophy of the APT system is first to eliminate many of the detailed operations associated with part programming; second, to achieve uniformity among all director systems. This is done by interposing, between the human part-programmer and the director system, a general-purpose digital-computer programmed to understand part-programming instructions written in an easy-to-use English-like language.

Scope of Phase I

The present scope of APT-II system is limited; its input language is primarily two-dimensional (although the calculating routines are fully three-dimensional) and contains full preprocessing facilities only for points, lines and circles. However, the vocabulary permits specification of quadratic curves in two dimensions such as ellipses, hyperbolas or parabolas, and the basic quadric surfaces in three dimensions such as planes, spheres, cones, cylinders, ellipsoids, hyperboloids, and paraboloids.

The present APT vocabulary consists of 107 words of six or fewer letters; numbers are also used to identify geometric features and tolerances where needed. The basic requirement of the human programmer is a knowledge of geometric construction with ruler and compass. The system will allow a wide variety of cutter shapes to be used, including flat end-mills, ball end-mills, filleted end-mills, conical cutters, etc.

How APT System Is Used

(a) A conceived part is drawn in detail.
(b) A part program of geometric definitions and machining sequence is made in English-like APT vocabulary.
(c) Part program statements are punched into cards for APT computer to read.
(d) A set of approximately 10,000 master cards are read-in general-purpose computer, enabling it to understand statements in APT language. Thus, the general-purpose computer is transformed into an APT computer.
(e) The part program cards are fed into the computer. The computer calculates cutter positions and sequence of travel, and a punched tape is obtained in machine tool director code. At this stage the computer can also project cutter movements on a television screen for visual verification.
(f) Punched tape causes numerically controlled tool to produce part.

Current Limitations of Phase I

No effort has been made to supply a convenient English-like vocabulary for full three dimensional operation. The system has no provisions for transformation of coordinates or automatic cleanout of pockets. Also, no means are provided for automatically compensating the effective cutter radius if the entire surface of the cutting tool is not in contact with the workpiece. This is the case of the shallow pocket, with sloping bottom, which is to cut by a filleted end-mill whose corner radius is much greater than the pocket depth. During this operation, the effective tool radius veries continuously because part of the corner radius curve is above the depth of the pocket side.

The above shortcomings are already being coped with, and a number of improvements will soon be incorporated into the system.

Advantages of APT System

- It uses programming terms similar to human terms, therefore requires less skill from individual programmer.
- It offers a standardized automatic programming system adaptable by any company possessing a general purpose computer.
- It is designed to meet long-range requirements of future numerical-control applications by "fleshing out" of present "general skeleton program."
- Manhour reductions realized over manual programming have ranged 80 to 95 per cent.
- Although the present APT-II system is extensive, and is rapidly exceeding the substantial capacity of the IBM 704 computer, the concepts involved do not necessarily require a large computer. With moderate loss of flexibility and capability, benefits can be achieved on medium-sized, and possibly small computers, especially by running the program in sections.

The cooperative effort for refinement and development of the current APT System will be managed by the APT Project Coordinating Group of Aircraft Industries Association's Numerical Control Panel which operates under the Technical Service Section of the AIA. The AIA program provides for participation by qualified and equipped non-AIA members. Prerequisites for participation are possession or access to a suitable computer and a willingness to accept and execute task assignments from the Coordinating Group. AIA forecasts a two year program to accomplish certain targeted refinements of the APT

System. This time will be substantially foreshortened if qualified segments of national industry participate in the effort.

Present scheduling calls for the early release of the remainder of the APT documentation prepared by MIT under Air Force contract. These data will consist of six separate volumes. Initial distribution will cover participating AIA members and other companies[1], as well as a broad segment of national industry, research organizations, etc.

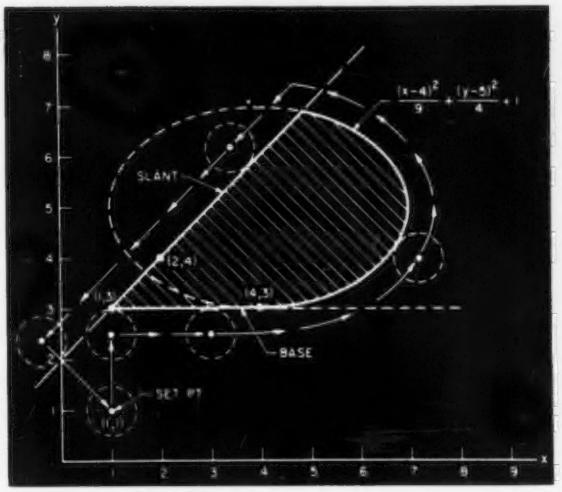
Documented revisions resulting from the APT Project refinement effort will be available at a nominal charge from AIA's Los Angeles Office.[2]

1. Bell (Buffalo); Boeing (Seattle); Chance Vought (Dallas); Convair (Fort Worth); Convair (San Diego); Douglas (Long Beach); General Motors Research Center (Detroit); Goodyear (Akron); IBM (White Plains, N. Y.); Lockheed (Marietta) Lockheed (Burbank); Marquardt (Van Nuys, Calif.); McDonnell (St. Louis); Martin (Baltimore); Martin (Denver); MIT (Cambridge); North American (Columbus); North American (L. A.); North American Rocketdyne (Canoga Park, Calif.); Northrop (Hawthorne); Republic (Farmingdale, N. Y.); Union Carbide (Oak Ridge); United Aircraft (East Hartford).

2. Inquiries should be addressed to Technical Service, Aircraft Industries Association 7660 Beverly Blvd., Los Angeles 36, Calif.

this article continues on next page

A simple example of APT programming is illustrated below. The part boundary in this case consists of two straight lines and a portion of an ellipse. The cutting sequence and the symbolic names, assigned to the required curves by the programmer, are seen in diagram below. The programming in APT language is given at the bottom of this page.



The information given about the part is as follows:

1. The equation of the ellipse in terms of the x,y, coordinate system shown is given by

$$\frac{(x-4)^2}{9} + \frac{(y-5)^2}{4} = 1$$

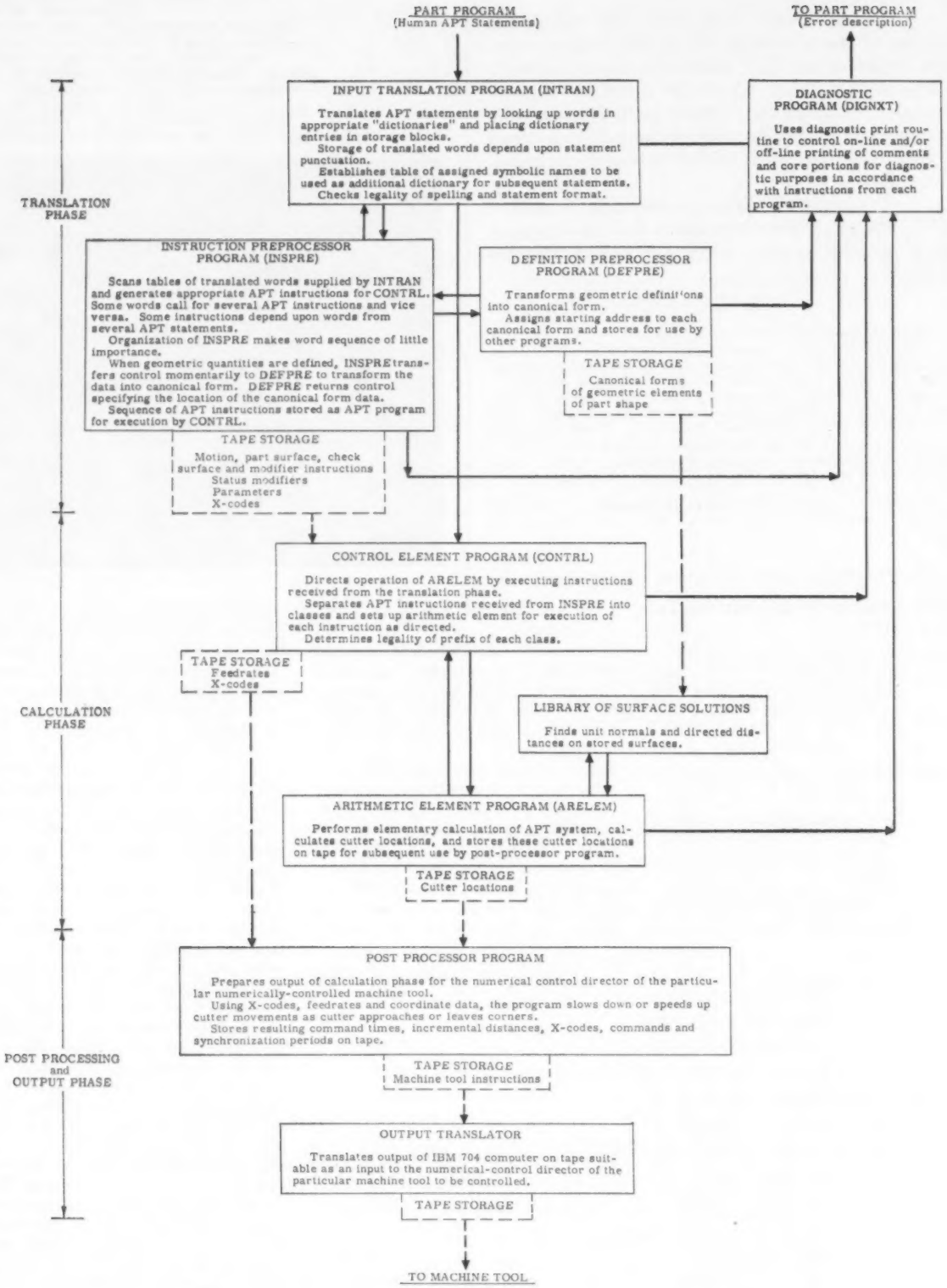
2. The lower line is to pass through the point x=+ 1 in., y=+ 3 in. (in mathematical notation (+1., +3.)) and is to be tangent to the bottom of the ellipse.
3. The slanting line is to pass through the same point and also through the point (+2., +.4).

Let's assume that the part is to be machined from half-inch aluminum stock to a finished tolerance of 0.010 in. Also, that a side mill of one in. diam will be used at a feedrate of 80 in./min.

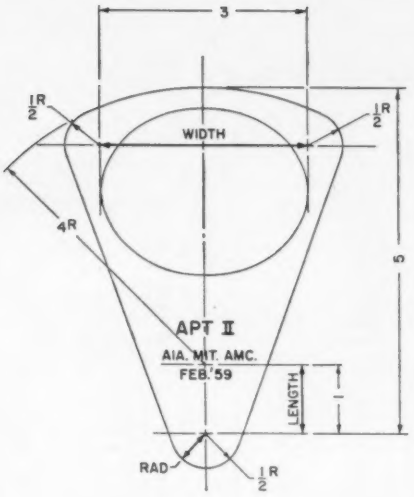
The part program translated into conventional English commands states the following:

"Use a flat end tool of 1-in. diam. Cut all curves by choosing straight-line cuts so that (excluding machine variations) the deviation between the desired curve and the broken line does not exceed 0.005 in. Cut all curves at a feedrate of 80 in./min. Use head No. 1, operating in mode No. 1, turn on the spindle, and turn on the coolant flow. Assume that the tool starts from the point with coordinates x = 1, y = 1, i.e., in mathematical notation (1,1). Call this point SET PT. From the point (1,1) aim in the direction of the point (1,3). Give that point the name TIP. Go in a straight line to the line through TIP which makes an angle of zero degrees with the positive x axis. Give this line the name BASE. With the tool on the right-hand side as you go, go right along the line BASE. When you come to the ellipse whose numerical parameters are 4,5, etc., go forward along that ellipse, still keeping the tool on the right-hand side. When you come to the line through the point (2,4) and the point (1,3), keep the tool on the right but go left along the line. In other words, keep the tool on the ellipse until the trailing edge of the tool is tangent to the line. Keep going along that line until the tool is on the far side of the line BASE. Then go in a straight line to the original starting point, whose name is SET PT. When you reach that point, turn off the coolant, and turn off the spindle. This is the end of the machine tool director operation, and the finish of the part program."

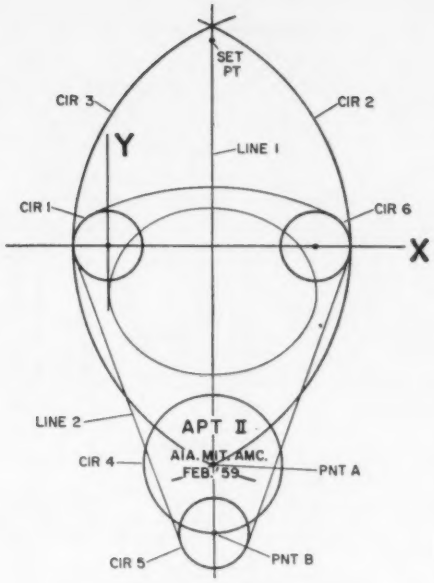
```
          TL DIA/+1.0, INCH
          TOLER/+.005, INCH
          FEDRAT/+80.,IPM
          HEAD 1, MODE 1, ON SPIN, ON KUL
SET PT  = FROM, POINT/1,1
  TIP   = IN DIR, POINT/1,3
 BASE   = GO TO, LINE/THRU, TIP, AT ANGL, 0, DEG
          GO RGT, WITH, TL RGT, ALONG/BASE
          GO FWD, ALONG, ELLIPS/4,5,0,+.33333,0,0,0,+.5,0
          GO LFT, ALONG, LINE/2,4,1,3
          GO PAST/BASE
          GO TO/SET PT
          OF KUL, OF SPIN, END, FINI
```


PART PROGRAM
(Human APT Statements)
TO PART PROGRAM
(Error description)
INPUT TRANSLATION PROGRAM (INTRAN)
Translates APT statements by looking up words in appropriate "dictionaries" and placing dictionary entries in storage blocks.
Storage of translated words depends upon statement punctuation.
Establishes table of assigned symbolic names to be used as additional dictionary for subsequent statements.
Checks legality of spelling and statement format.
DIAGNOSTIC PROGRAM (DIGNXT)
Uses diagnostic print routine to control on-line and/or off-line printing of comments and core portions for diagnostic purposes in accordance with instructions from each program.
TRANSLATION PHASE
INSTRUCTION PREPROCESSOR PROGRAM (INSPRE)
Scans tables of translated words supplied by INTRAN and generates appropriate APT instructions for CONTRL. Some words call for several APT instructions and vice versa. Some instructions depend upon words from several APT statements.
Organization of INSPRE makes word sequence of little importance.
When geometric quantities are defined, INSPRE transfers control momentarily to DEFPRE to transform the data into canonical form. DEFPRE returns control specifying the location of the canonical form data.
Sequence of APT instructions stored as APT program for execution by CONTRL.
DEFINITION PREPROCESSOR PROGRAM (DEFPRE)
Transforms geometric definitions into canonical form.
Assigns starting address to each canonical form and stores for use by other programs.
TAPE STORAGE
Canonical forms of geometric elements of part shape
TAPE STORAGE
Motion, part surface, check surface and modifier instructions
Status modifiers
Parameters
X-codes
CONTROL ELEMENT PROGRAM (CONTRL)
Directs operation of ARELEM by executing instructions received from the translation phase.
Separates APT instructions received from INSPRE into classes and sets up arithmetic element for execution of each instruction as directed.
Determines legality of prefix of each class.
TAPE STORAGE
Feedrates
X-codes
CALCULATION PHASE
LIBRARY OF SURFACE SOLUTIONS
Finds unit normals and directed distances on stored surfaces.
ARITHMETIC ELEMENT PROGRAM (ARELEM)
Performs elementary calculation of APT system, calculates cutter locations, and stores these cutter locations on tape for subsequent use by post-processor program.
TAPE STORAGE
Cutter locations
POST PROCESSOR PROGRAM
Prepares output of calculation phase for the numerical control director of the particular numerically-controlled machine tool.
Using X-codes, feedrates and coordinate data, the program slows down or speeds up cutter movements as cutter approaches or leaves corners.
Stores resulting command times, incremental distances, X-codes, commands and synchronization periods on tape.
POST PROCESSING and OUTPUT PHASE
TAPE STORAGE
Machine tool instructions
OUTPUT TRANSLATOR
Translates output of IBM 704 computer on tape suitable as an input to the numerical-control director of the particular machine tool to be controlled.
TAPE STORAGE
TO MACHINE TOOL

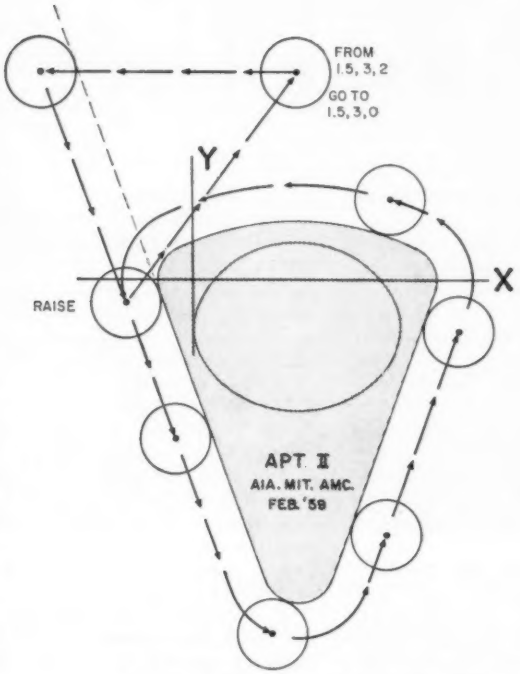
FUNCTIONS OF APT SYSTEM PROGRAMS



PART CONFIGURATION CODE



PART CONFIGURATION DEFINED IN TERMS OF CIRCLES AND LINES



TOOL PATH FOR CUTTING FITTING BOUNDARY

```
REMARK   FITTING OUTSIDE CUT
WIDTH = + 3., INCH
LENGTH = + 1., INCH
RAD = +.5, INCH
      TL RAD/+ .5, INCH
      TOLER/+ .01, INCH
      FEDRAT/+ 7.5, IPM
      MAX DP/+ .125, INCH
      2DCALC, PS IS, PLANE/+ 0., + 0., +1., +0.
SET PT = FROM, POINT/+ 1.5, + 3., + 2.
      GO TO/+ 1.5, + 3., + 0.
      IN DIR, VECTOR/ - 1., + 0., + 0.
CIR 1 = CIRCLE/CTR AT, + 0., + 0., RADIUS, + .5, INCH
CIR 2 = CIRCLE/CTR AT, + 0., + 0., RADIUS, + 3.5, INCH
CIR 3 = CIRCLE/CTR AT, WIDTH, + 0., RADIUS, + 3.5, INCH
PNT A = POINT/Y SMALL, INT OF, CIR 2, WITH, CIR 3
CIR 4 = CIRCLE/CTR AT, PNT A, RADIUS, LENGTH
LINE 1 = LINE/THRU, PNT A, AT ANGL, + 90., DEG
PNT B = POINT/Y SMALL, INT OF, LINE 1, WITH, CIR 4
CIR 5 = CIRCLE/CTR AT, PNT B, RADIUS, RAD
LINE 2 = LINE/RIGHT, TAN TO, CIR 1, AND, RIGHT, TAN TO, CIR 5
      TL RGT, GO PAST/LINE 2
      GO LFT/LINE 2
      GO FWD/CIR 5
CIR 6 = CIRCLE/CTR AT, WIDTH, +0., RADIUS, + .5, INCH
      GO FWD, LINE/RIGHT, TAN TO, CIR 5, AND, RIGHT, TAN TO,
        CIR 6
      GO FWD/CIR 6
      GO FWD, CIRCLE/CTR AT, PNT A, RADIUS, + 4., INCH
      GO FWD/CIR 1, UNTIL, TOOL, TAN, LINE 2
      GO DLTA/ + 0., + 0., + 1.5, INCH
      GO TO/SET PT
      END, FINI
```

continued on next page

APT . . . continued

COMPLETE INITIAL VOCABULARY FOR THE APT II SYSTEM.

Symbol	=	Major Section Words (Separated by Commas)		/	Minor Section Words (Separated by Commas)	
Symbols (Examples)		**Motion Instructions**			**Definition Modifiers**	
A1		FROM	O		TO	O
2S32		IN DIR	O		ON	O
SET PT		GO TO	O		PAST	O
Y AXIS		GO ON	O		TAN	O
LINE 5		GO PAST	O		CTR AT	O
JOHN		GO TAN	O		AT ANGL	O
Special Words		GO DELTA	O		RADIUS	O
REMARK		GO RGT	O		INT OF	T
		GO LFT	O		TAN TO	T
		GO FWD	O		X LARGE	T
		GO BAC L	O		X SMALL	T
		GO BAC R	O		Y LARGE	T
		GO UP	O		Y SMALL	T
		GO DOWN	O		Z LARGE	T
		Special Instructions			Z SMALL	T
		Z SURF	M		RIGHT	T
		TN CK PT	M		LEFT	T
		LOOK TN	M		LARGE	T
		LOOK DS	M		SMALL	T
		LOOK PS	M		**Numbers (Examples)**	
		2D CALC	M		+123.4	
		3D CALC	M		-0.01234	
		PS IS	M		+123	
		FINI	O		-123	
		Ignorables			123	
		WITH AND			**Pre-Defined Symbols**	
		ALONG				
		INCH				
		DEG				
		IPM				
		THRU				
		UNTIL				
		JOINT				
		TOOL				

Modifiers	
TL LFT	M
TL RGT	M
TL ON	M
CUT	O-M
DNT CUT	O-M
NEAR	O-M
FAR	O-M
2	T
3	T
4	T
Director Words (Concord Control)	
MODE 1	M
MODE 2	M
MODE 4	M
P STOP	O
STOP	O
HEAD 1	M
HEAD 2	M
HEAD 3	M
OF KUL	M
ON KUL	M
END	O
LOKX	M
ULOKX	M

Geometric Names	
POINT	O
LINE	O
CIRCLE	O
ELLIPS	O
HYPERB	O
PARAB	O
PLANE	O
SPHERE	O
CONE	O
CYLNDR	O
ELL CON	O
ELL CYL	O
PAR CYL	O
HYP CYL	O
TAB CYL	O
ELLPSE	O
ELL PAR	O
HYP PAR	O
HYPLD 1	O
HYPLD 2	O
QADRIC	O
VECTOR	O
Parameter Names	
TOLER	M
FEDRAT	M
MAX DP	M
TL RAD	M
TL DIA	M
COR RAD	M
COR DIA	M
BAL RAD	M
BAL DIA	M
GNRL TL	M

The APT part programming language is a true language and not merely a coding scheme. By defining four types of statement and four types of word meaning or modifying power, the correct word usage can be described. There are four types of APT statements containing one, two, or three principal sections, separated by distinguishing punctuation characters. These statement types are called: (1) definition statement; (2) instruction statement; (3) synonym statement; (4) special statement. The most elaborate type of statement is the "definition statement" which has the form:

symbol = major section/minor section

An "instruction statement" has the form:

major section/minor section

A "synonym statement" involves a symbol and has the form:

symbol = minor section

The special statement consists only of a major section. The sign =, and the sign / are used as punctuation marks.

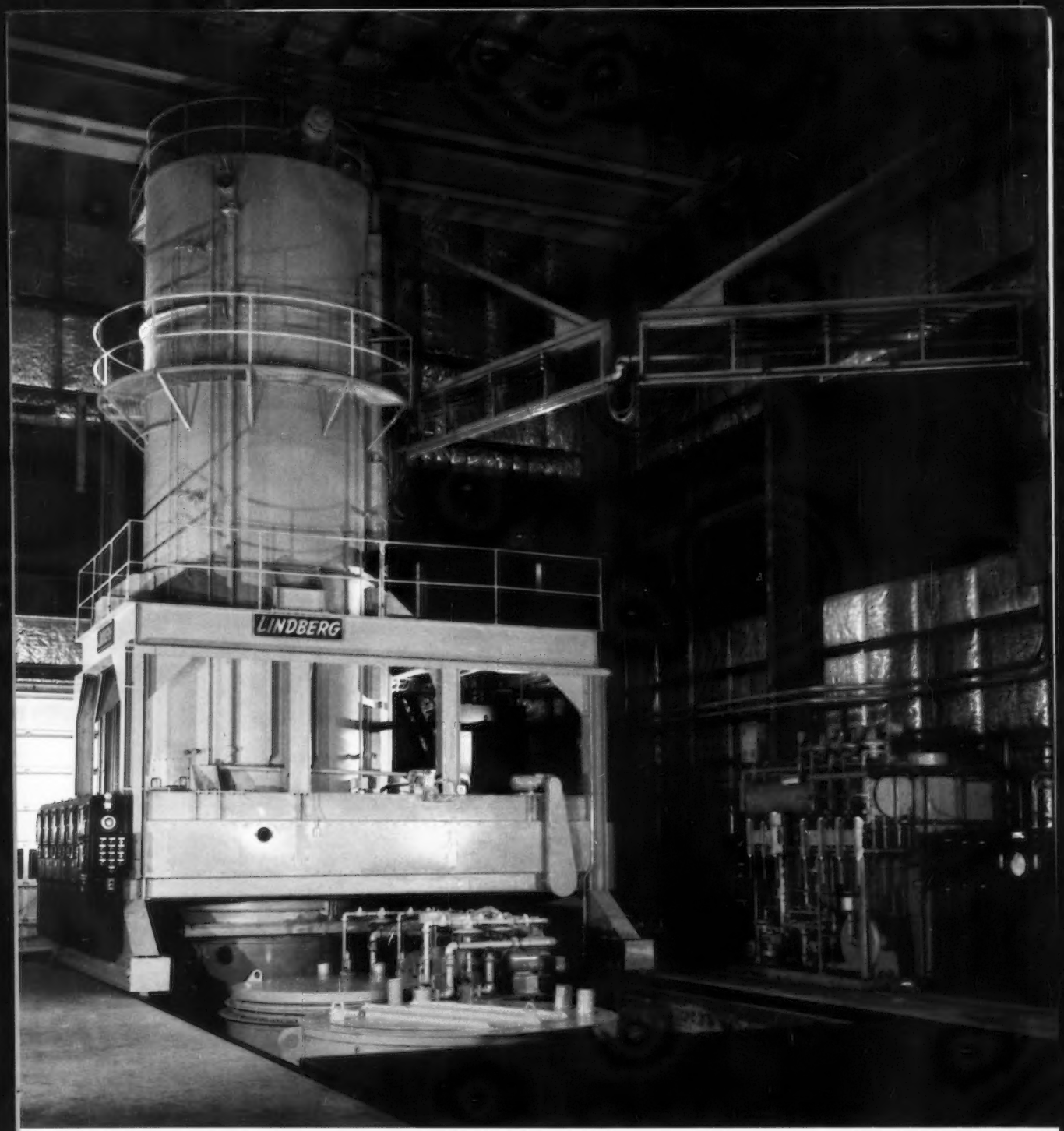
Any time a word is written down, its meaning applies to a greater or lesser extent to control or influence how the APT system will instruct the machine-tool director. In other words, each word exhibits a certain modifying power with respect to the overall meaning of the entire part program. There are four levels of modifying power which are distinguished in the APT system. These are called modal (M), one-shot (O), transient (T), and variable one-shot or modal (O-M).

A word which has "modal" meaning need be written only once in the part program, after which its meaning applies to all succeeding statements until another word from the same set is given. For example, if the instruction TL LFT is written, then the tool will be placed on the left-hand side of the cut for all cuts, unless in some later statement another word from the same set, such as TL RGT, takes over. "One-shot" words apply only to the statement in which they occur and do not modify the meaning of words in other APT statements. Thus, the word FROM, which specifies the location of the tool center, has meaning only in the single statement in which it occurs.

The variable "one-shot or modal" words have either "one-shot" or "modal" meaning depending upon what type of statement they are used in. If they are used in a special statement they have "modal" meaning, whereas if they are used in a definition or instruction statement (i.e., a statement punctuated with a /) their meaning is "one-shot".

"Transient" words modify only the word immediately preceding or the word immediately following their occurrence. Thus the combination FAR, 3, means the third far intersection; whereas the combination X SMALL, INT OF, means the intersection with the smallest X coordinate. ✦

Circle 12 on Inquiry Card, page 83 ⟶



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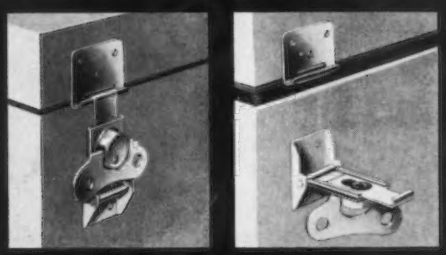

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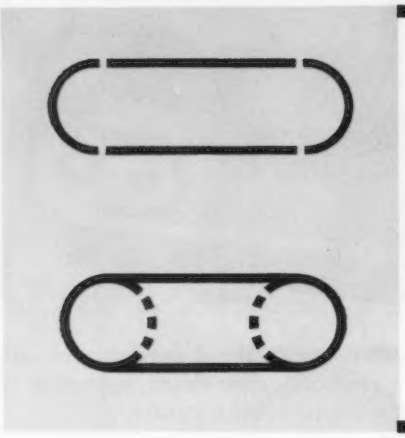


pressure vessels

by John P. Kushnerick

a study of some successful materials and processes

Unprecedented demands are being placed on pressure vessels in missiles, and the coming generation of aircraft. These demands are created by: (1) the use of tankage as an integral airframe structure, (2) the highly corrosive nature of most oxidizers, (3) the extreme temperature ranges experienced with liquefied gases, (4) the high tank-pressures common to solid propellant systems.

Most of these demands have been encountered, either singly or in combination, in other industries. But, the knowledge gained in manufacturing pressure vessels in other industries has been of limited use. This is because the problems have been intensified in aircraft and missiles by attempts to:

- Maximize strength-to-weight ratio.
- Increase reliability by several orders of magnitude.
- Insure good dimensional stability.
- Use new materials, and hence new methods of construction.
- Minimize costs.

Weight reductions and higher strengths are achieved by using new high-strength metals with "thin" wall dimensions. As an example, some "ground bound" boiler systems can use material thicknesses which give a 10 to 1 safety factor. In missile pressure vessels, this ratio is more like 1.1 to 1 (based on yield strength and UTS as dictated by application)[1].

Reliability is increased by extreme quality control throughout the manufacturing sequences of forming and joining. Akin to reliability is dimensional stability achieved by proper planning of tank geometries, and use of tooling methods which will faithfully reproduce the designed shapes.

Cost is kept to a minimum by intelligent choice of materials and methods. These are always difficult to pin down, since it may be economical for one company to use a method that to another would be prohibitive. Existing machinery plays a large part in the final analysis. Getting the most from the fabrication method selected, however, is essential.

Configuration and Processes of Construction

The majority of fuel pressure-vessels are of two general configurations:

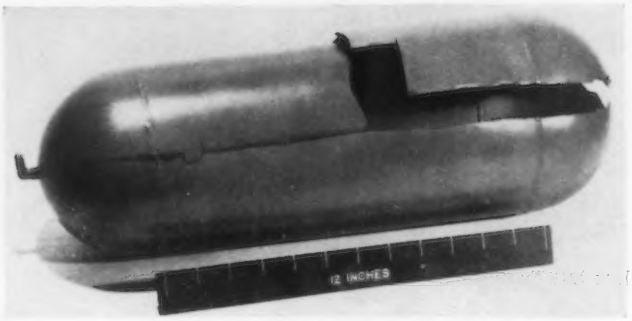
- Spherical.
- Cylindrical with hemispherical head.

Spherical vessels are most common in aircraft systems and liquid-fueled missile systems. They usually store liquefied gases, and hence, in use, are subject to a very cold, induced, environment (about −320°F). The methods most commonly used to fabricate the hemispheres that are circumferencially welded into a spherical geometry are:

- Spinforming.
- Deep drawing.
- Hydroforming.

Cylindrical vessels are used in solid-fuel, rocket motor-cases, as well as in liquid-fuel systems. They present a more complex fabrication problem because they are made up of more pieces of metal, and hence require more joining. The cylindrical section is made from sheet stock, rolled to the desired diameter and longitudinally

pressure vessels . . . continued



Small cylindrical pressure vessel of Potomac A was tested at Solar Aircraft to 270,000 psi. Burst occurred in longitudinal weld and in parent material. Hoop stresses are most severe.

seam welded. The major disadvantage of this fabrication technique is the lengthy longitudinal weld. Hoop stress is usually the greatest force imposed during firing, hence, the longitudinal weld must be very strong. Weld placement and joint design are sciences in themselves and cannot be covered here, except to say that most organizations consider a joint inadequate if it fails simultaneous with, or before, the parent material.

Accurate size control is important; in some large, 40 in. diam, solid motor-cases "roundness" on the order of 0.125 in. is considered critical. Diameter tolerances are in the order of ± 0.020 or 0.030 in. Despite the best fixturing the state of the art is able to provide for fabrication; welding, and/or heat treatment can cause distortion. Where distortion is great, expandable "mandrels" are used to restore dimensional tolerance. This type of mandrel is usually composed of about eight radial segments. Each segment covers about 18 in. arc-wise, and about 24 in. lengthwise. Most are designed specially for only one or two projects, and exact operation is guarded as proprietary information.

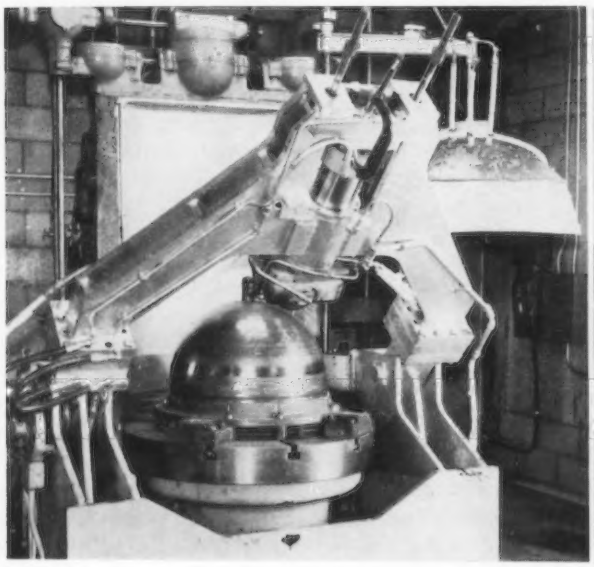
Materials of Construction

There is diversity in the choice of materials of construction. But, the requirements for ductility, weldability, dimensional stability, etc., narrow the choice. Of the ferrous metals, martensitic alloys are seldom if ever considered. Strength-to-weight ratio is better in some grades of titanium than in the austenitic alloys, however, dimensional stability and weldability problems are present in some of the Ti-alloys.

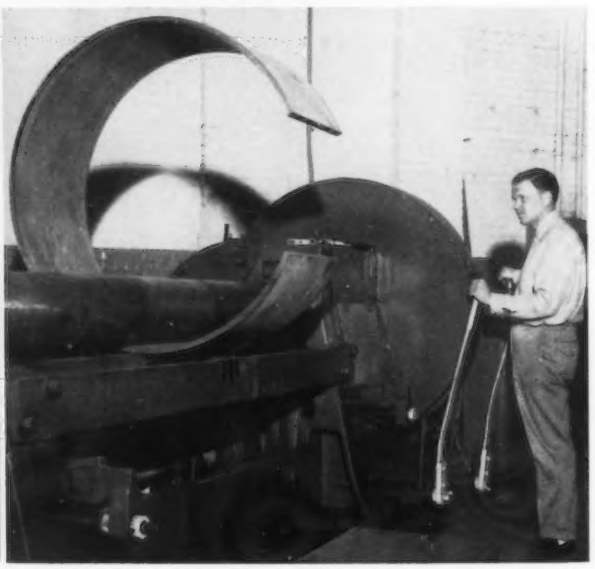
For the ballistic variety of missiles, motor cases are being fabricated of modified 4340, 4130, modified 5 per cent chrome steel, AMS 6434, Tricent (M-3000), AISI 4640, Vasco Jet 1000, Airsteel X200 and other similar materials.

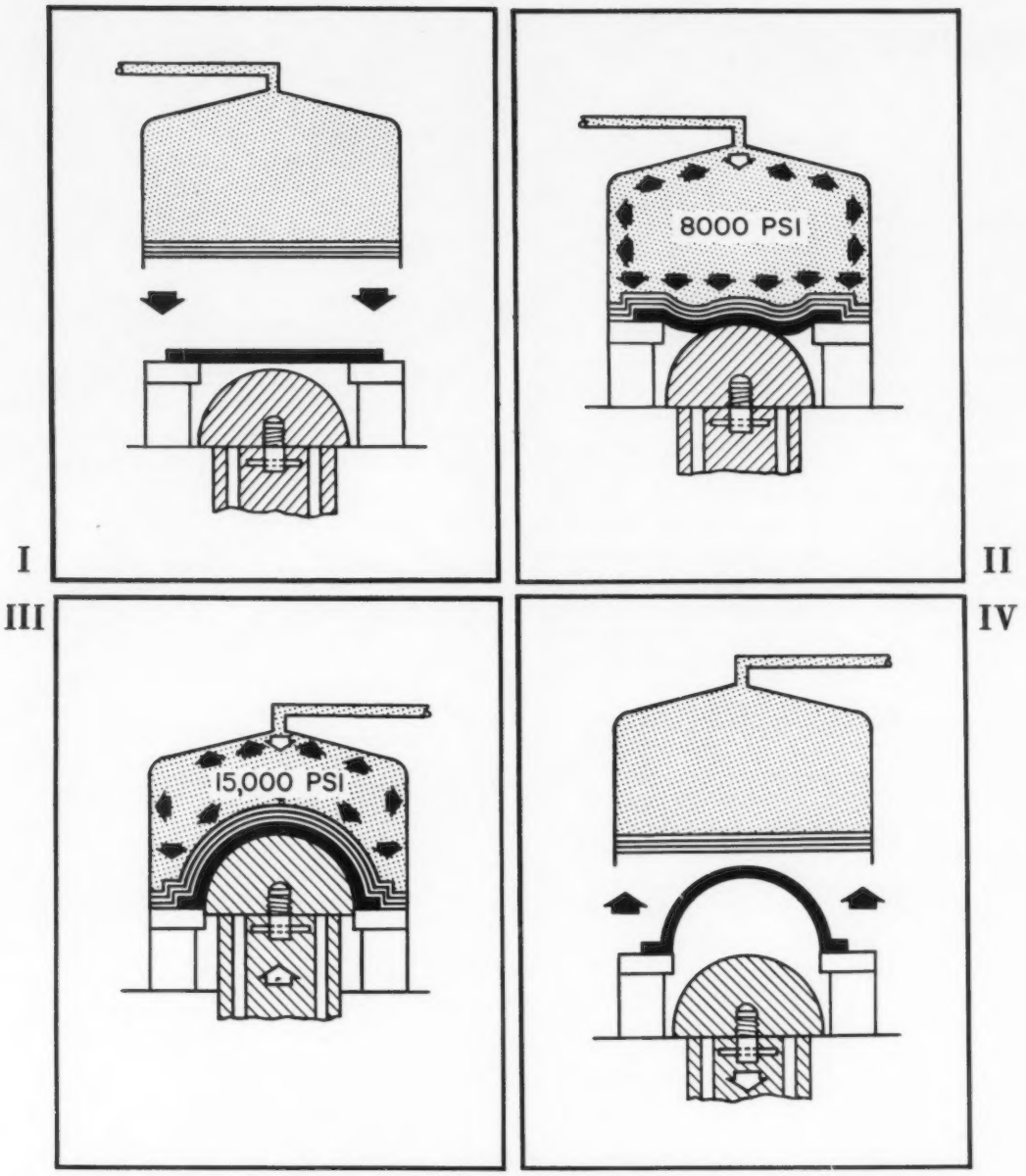
There is a growing belief in many quarters that the oil-hardenable steels are inherently inadequate. This has turned attention to the

Spinforming is one way of fabricating hemispheres. Here, specialized "hot roll-spinner" by Titanium Fabricators is shown with heat applicator swung away from work piece. Used for Atlas tanks of Ti-6A1-4V.



Tank section for high-volume liquid-fueled missile is rolled to roundness before welding. Other sleeves and two hemispherical heads will be welded to complete the tank. Material is precipitation hardening steel.





Hydroforming is another way of forming hemispheres. (1) Workpiece is positioned on table, (2) Pressure dome is lowered and hydraulic pressure applied, (3) Punch is forced up against increased hydraulic pressure, part is formed between rubber diaphragm and punch. (4) Punch is lowered, dome lifted, and part removed. Little part thin-out occurs since this is not a drawing operation.

air-hardenable variety. Pursuing this course, Solar Aircraft has investigated 12 Mov, Potomac M, Vasco Jet 1000, Thermold J, and Peerless 56. Conclusions are that air-hardenable 12 Mov (12.5 Cr, 0.20C, 1.0 Mo, 0.20V), and the hot-work die steels mentioned (5.0 Cr, 0.35 to 0.50 C, with minor Si, Mo, and V) can be heat treated to higher strengths than others of the commercially available structural materials. This strength advantage is maintained to 1000°F. UTS is about 290,000 psi under optimum conditions.

It has been found that these materials in the annealed condition are readily formed and drawn. Annealed ductilities are on the order of 18 to 23 per cent. Sound welds were produced manually and automatically with tungsten arc on small (6 to 18 in. diam) samples.[2]

The Budd Co. is presently working with materials like AM355, reasoning that the expensive, and time-consuming heat treatment of the entire case can be eliminated. The diam of these cylinders is about 40 in., and may be used in the Minuteman. Theory is yet to be proven feasible.

continued on next page

pressure vessels . . . continued

Titanium Outlook Brightens

Titanium alloys have been used widely in spherical containers, and have been evaluated for cylindrical shapes. Ti-6A1-4V has given consistently good results for spheres. Since titanium has already matched ferrous alloys, in some areas, with only a short development time, some metallurgists think it must inevitably surpass in other areas. This is because the rate of improvement in the ferrous alloys is decreasing, while in titanium, alloying and fabricating is gathering new momentum.

There is also evidence that original temperature parameters for rocket motor cases were on the high side at 1000°F. Actual operating temperatures are several hundred degrees less. This may enhance the position of titanium alloys.[1]

Airite Deepdraws

Airite Products Inc., has had success with C-120AV (6 per cent Al, 4 per cent V) in fabricating helium pressure-vessels for the Atlas ICBM. Fabrication technique involves deep drawing, machining, welding, and heat treatment to higher strength. The operation begins with ⅜-in. plate, coated to guard against oxidation. Deep drawing is performed hot, in one draw, to 13 or 15-in. depths. This allows for machining and trimming to obtain finished hemispheres of 21.5 and 24.5 in.-diam respectively. Machining is done on both the inside and outside surfaces. Welding is accomplished in inert-gas chambers. Solution heat-treatment, quenching, and aging under optimum conditions give a 160,000 psi yield strength.[3]

From the designers standpoint, deep drawing offers the advantage of having triaxial stresses applied externally during forming, which closely approximate internal stresses applied during operation.[4]

Spinforming

Titanium Fabricators Inc., has become convinced that an opposing method of manufacture, hot-roll-spinning, is more practical and less expensive. TIFAB has alo fabricated spheres for Atlas. This company has been so strong in its belief that its own approach is the more logical, that it designed its own vertical roll-spinning machine. As in most spinforming operations, workpiece is formed over an inexpensive ductile-iron, male mandrel. The rollar pressure in this tool is applied through an hydraulic ram, mounted on a yoke. Yoke can be swung from one side of the rotating mandrel to the other. Shapes are precisely controlled in contour and in thickness. Cross-section thickness can be varied by varying ram pressure as the roller passes over certain points on the mandrel. This is difficult.

The theory of forming involved in this machine is comparable with that in plate rolling. Shear spinning is also a factor, but the severe grain orientations common in shear spinning are not experienced in roll spinning.

TIFAB states that costs of forming particularly heavy sections are less by this method, as opposed to deep drawing. The exception is where "very large" production lots are involved. Tooling is less expensive, more quickly made ready, requires less development and tryout time before production can begin.[5]

In roll forming the Atlas pressure-vessels, Ti-6A1-4V was used. Blanks about ⅜ in. thick were treated with a special anti-oxidation material. In early vessels, the blank was preheated. This was subsequently eliminated and heat was applied only during forming. Temperature of 1000 to 1350°F was applied by a combination of electrical and torch heat. (In a new spinforming machine, the mandrel is heated electrically, and work piece with gas torches.) Hemispheres were spun in two stages, i.e., over two separate mandrels. Oxidation of the titanium alloy was minimized through a coating, and keeping the part at working temperature for a minimum of time. Oxidation which did occur was removed by either machining, chem-milling, or polishing. Finished wall thickness was about 0.250 in., 0.320 in weld areas.

Strengths to 120,000 psi yield were achieved by a vacuum anneal.

Seamless Cylinders

Parts up to 60 in. in diam are feasible with this method of fabrication. Development pieces are now being run which show that head and sleeve can be fabricated together in cylindrical tanks. Hence, weld-free cylindrical vessels may soon be available, eliminating the most serious bugaboo in attaining reliable solid rocket motor cases. ◆

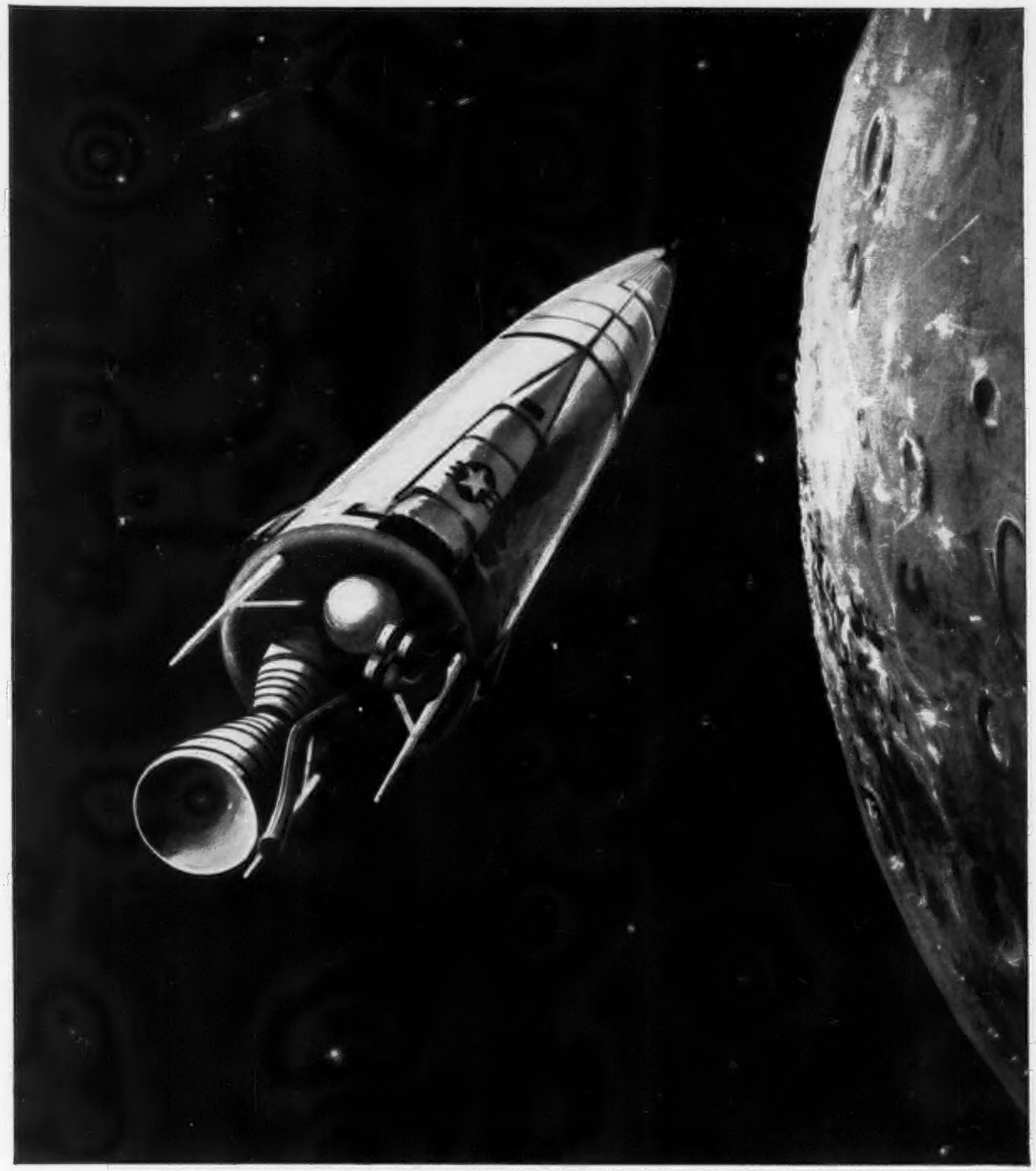
1. *Nulk, Donald E., Fuel Containers for Rockets, Metal Progress, March, 1959.*

2. *Fabrication and Mechanical Properties of Air Hardening Types of Low Alloy Steels, Solar Aircraft Co., Research Div. Report 1056-2A.*

3. *Crucible Titanium Review, March, 1959.*

4. *Garfield, Gerald, Tooling for Welded Aircraft and Missile Pressure Vessels, ASTE Paper 151, Oct., 1958.*

5. *Spiegl, Fred, Hot Roll Spinning Titanium, ASTE Paper 173, Oct., 1958.*



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Circle 14 on Inquiry Card, page 83

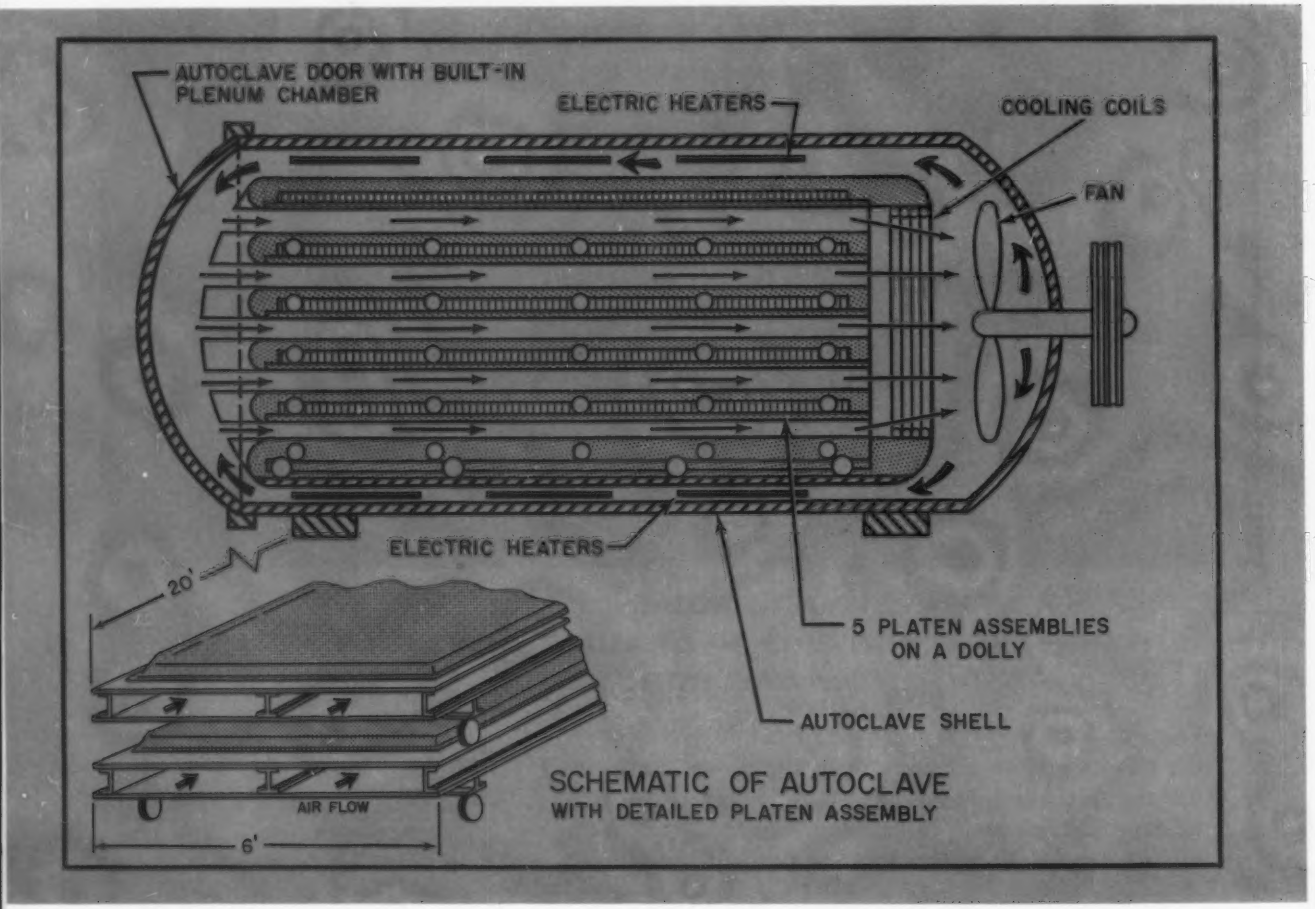
void-free bonds

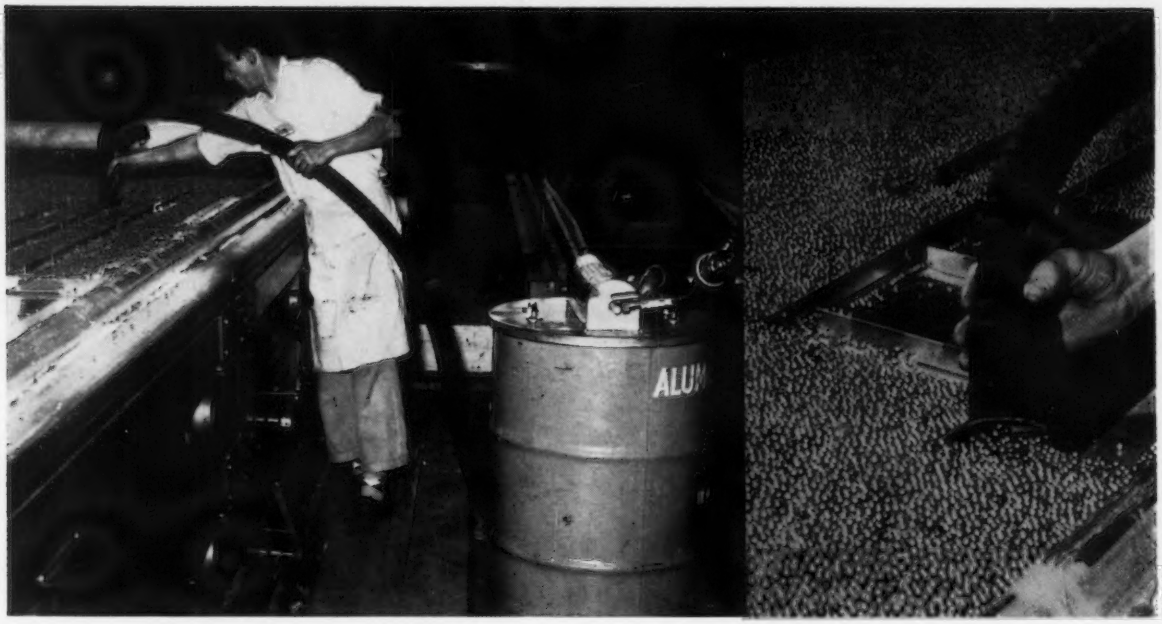
use of "ball-bonding" technique

insures good pressure and heat distribution

in fabricating B-52 honeycomb panels

by **R. F. Geiger**, project development manager, Twin Coach Co.





After curing, aluminum balls are removed from platen with suction. Dolly construction, and stacking of platens can be seen in this photo.

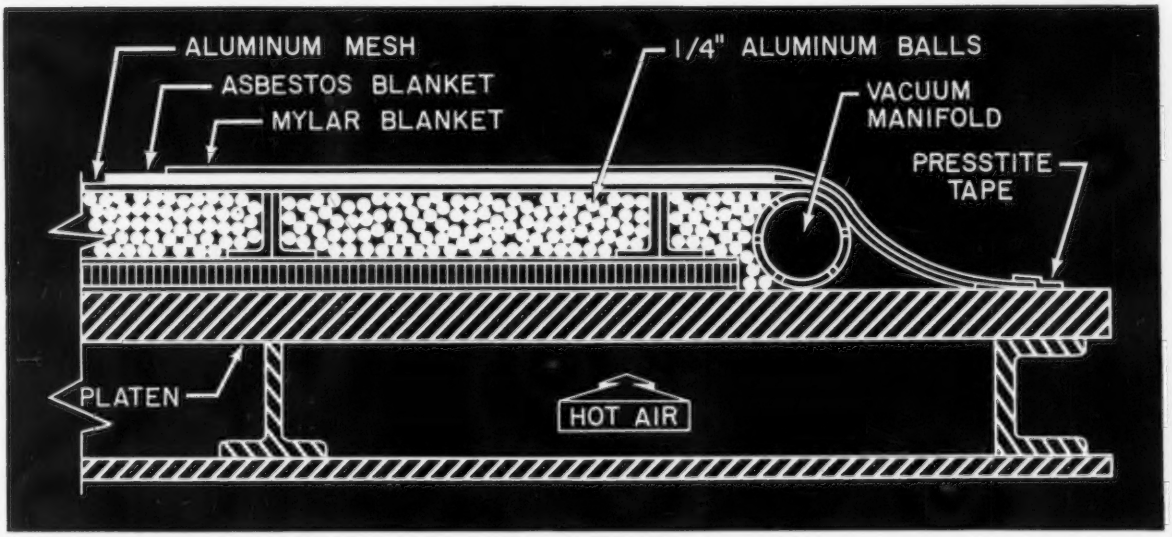
Balls are usually about six-deep. Angled dividers are used to prevent shifting and provide positive control of pressure in local areas.

Evenness, and completeness of pressure application is essential if void-free structures are to result in adhesive bonding.

Some difficulty has been experienced in obtaining satisfactory pressures in working with flat as well as contoured sandwich panels. These difficulties arise from: (1) wide range of nominal thicknesses allowed in sheet stock, Al 5 per cent, Mg 7 per cent, stainless 10 per cent; (2) slight irregularities on machined faces of honeycomb core.

To overcome these difficulties a technique called "ball bonding" has come into being. In this process, small aluminum balls, about ¼ in. diam, are spread over the sandwich layup to be bonded, and pressure is brought to bear on the balls. Pressure is then transmitted through the balls to the top skin of the assembly, through the core

BALL-BONDING LAYUP



and bottom skins, and finally to the bottom platen. The balls have the capability of compensating for slight surface irregularities. As a consequence, rejects resulting from "voids" (unbonded areas) have been reduced.

B-52 Flap Panels

An example of ball bonding in operation is found at Twin Coach Co., Buffalo, where Boeing subcontracts assemblies for B-52s.

Production Engineers at Twin Coach are given the drawings on a completed assembly, and by a reverse process, "breaking back," they decide the type and number of steps necessary to fabricate the part from its various components. Hence the term "eight-step break-back cycle" has come to identify the procedure used in making B-52 flap panels.

PRE-FIT is the first step in the fabrication process. The twenty-five details are deburred and tagged by part and assembly number. Each detail is then pre-fit on a reference layout template to assure marriage in the final part. Pre-fit tolerance is ± 0.010 to 0.030 in. A test coupon and an inspection record sheet accompany the details through the steps which follow.

PROCESSING AND CLEANING follows pre-fit. All details for one flap panel are processed together as an assembly lot. They are loaded on a cleaning hood and transported by overhead rail to the cleaning area with two to five other assembly lots. Clad aluminum parts are cleaned as follows:

Vapor degrease .....5 min.
Alkaline clean .....(Turco 2623)...10 min.
Spray rinse .....warm H_2O
Sulfuric Acid, sodium dichromate .....10 min.
Spray rinse .....cold H_2O
Dry .....forced hot air...at 140° time temp. (approx 15 min.)

Unclad aluminum details are given a chromic acid anodize followed by a cold water rinse. (Anodized details hot-water sealed do not bond as satisfactorily as those unsealed.)

ADHESIVE APPLICATION is accomplished in controlled atmosphere (40 to 50 per cent relative humidity at 75°F). Narmco's Metlbond 303 adhesive is used. This is a two part (liquid primer and elastomer tape) modified phenolic. The primer is sprayed on in two coats, an air dry of 30 min is observed between coats.

TAPING COMPONENTS follows a 120 min air dry of the second adhesive primer coat. The Metlbond 303 tape is a nylon fabric impregnated with a modified phenolic, and coated with an elastomer phenolic resin. The tape is heat-tacked on all faying surfaces. Details are inspected, appropriate entries are made on the record sheet, and parts are ready for assembly.

ASSEMBLING DETAILS is effected on meticulously clean tables in the same controlled atmosphere. Fixturing is used to facilitate correct location of details.

SETTING UP ON PLATENS brings the assembled details to the ball bonding fixtures. Together with their test coupons, the flap sections are placed within a frame. Numerous thermocouples are inserted in the glue line of the assemblies and these are monitored throughout the cure cycle. The hollow aluminum-balls are poured to a minimum depth of about six balls. An aluminum mesh is laid over the balls to prevent penetration of the succeeding layers when placed under pressure. Next, sheets of asbestos are rolled over the mesh to retain the heat. Finally, a Mylar film is used to "bag" the entire top of the platen assembly. As many as five assemblies may be bagged on one platen. Air is evacuated from beneath the Mylar and atmospheric pressure is brought to bear on the layup. A check is made for leaks.

Five such platens are loaded on a special dollie in the autoclave, the vacuum reapplied, and the thermocouples connected to their respective recorders. Here hot air is circulated and recirculated under the bottom of each platen by reverse flow ducts. A blower keeps the air in motion.

CURE is effected in 35 min at 325 to 350°F. Autoclave pressure is brought up to 90 psi during the heat up cycle and held for the duration of the cure.

INSPECTION is the last of the eight steps. Attention is given to final alignment of details and a check for voids. The test coupons which were cured along with the flap section are tensils tested to failure. Minimum value is 2400 psi.

✦

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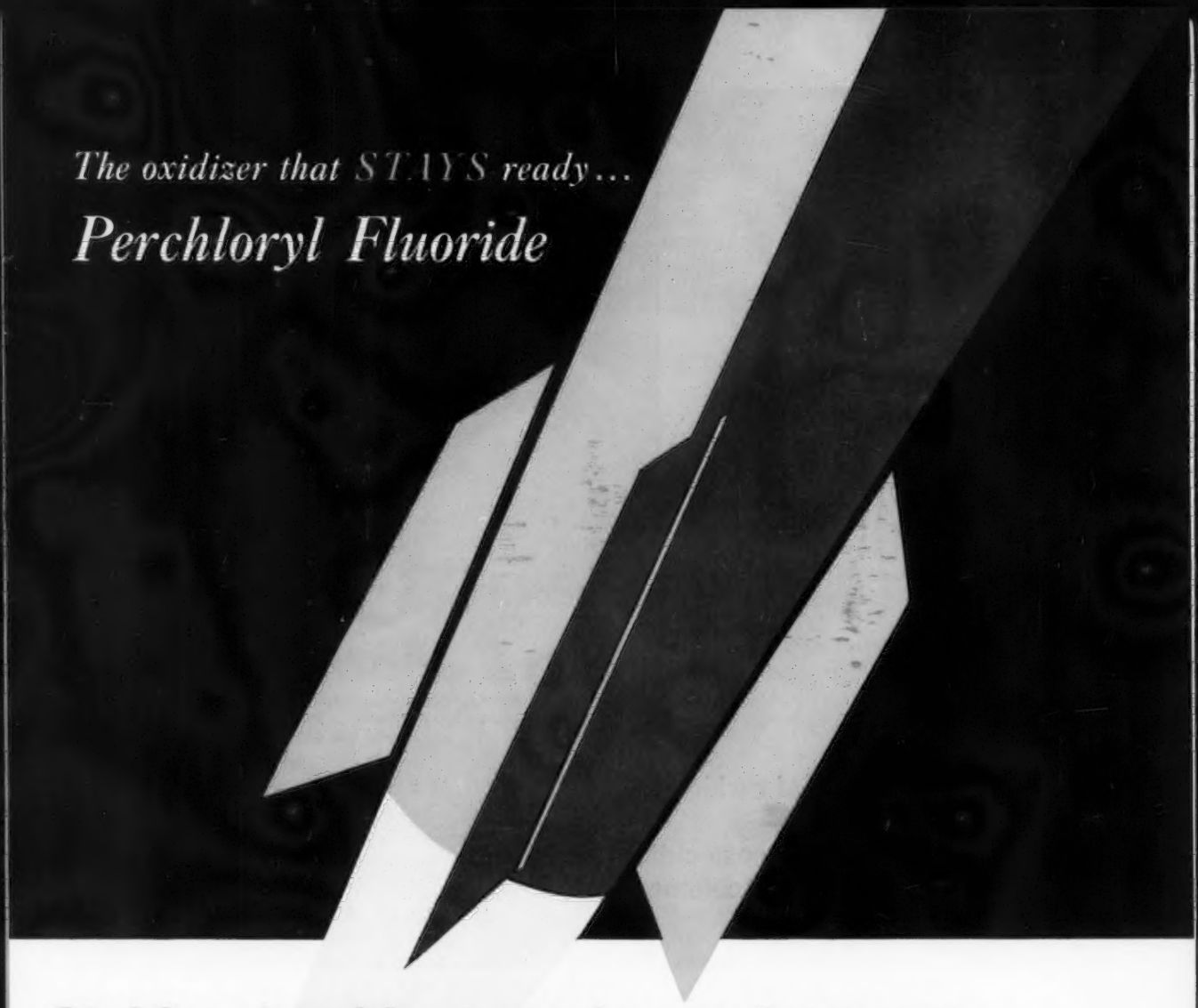
Circle 15 on Inquiry Card, page 83➔



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how to machine these HT alloys

by H. M. Schrier, design engineer,
Metallurgical Products Dept.,
General Electric Co.

Positive rake disposable toolholder is used to machine Rene '41. Overhang is minimized for rigidity and the chip is loosely curled.

erratic performance of carbide tools is main difficulty; low speeds, special-purpose cutting fluids, and positive-rake tools recommended

Machining the various high temperature alloys coming into aircraft and missile use is considerably different from machining such standard steels as AISI 1045 and 4340.

The main difficulty encountered is erratic performance of the cutting tools. This can be traced to the metal welding to the tool, and "pulling out" particles of the tool materials. Cemented carbides, even with their resistance to compressive shock and abrasion, are susceptible to this phenomena. This is particularly evident in milling operations where the chip adheres to the tip and is carried around until the cutter tooth reenters the work. At this point the chip is sheared away from the tool and with it go particles of the carbide.

The high temperature alloys can be grouped into three categories: iron base alloys, nickel base alloys, and cobalt base alloys. Examples of each are J-1300 (iron base), René 41 and J-1500 (nickel base), and J-1650 and J-1570 (cobalt base). These three groups are similar in the sense that they all have low machinability ratings. Some are "gummy"; the tool heat causes the material to build up on the tool, and results in minute chipping. If the metal has been hardened, the extreme abrasiveness of the material prohibits the use of high speeds and feeds. Work hardening of most of the high temperature alloys unfavorably affects tool life because there is a tendency to develop a notch on the cutting surface at the depth-of-cut line.

Nature of Tool Limitation

There are several reasons cemented carbide tools used on high temperature alloys cannot be operated at speeds used with ordinary alloy steel. Fig. 1 shows the beginnings of a failure where a carbide tool edge was used on an HT alloy. The lighter portion of the photomicrograph indicates buildup of the work material. The mechanism by which the alloy adheres to

the carbide appears to be a welding effect. Particles of the work material have also been forced into the tungsten. A breakaway will occur.

In machining HT alloys, buildup occurs in the cratered area or in the chip contact area. Temperatures induced by friction can be more than sufficient to cause welding. Further, the steady tool-tip contact continues to build up the weld. It finally attains a size sufficient to dislodge the buildup from the carbide. Strength of the weld is so high that the carbide fractures intergranularly, large carbide-cobalt agglomerates being pulled out with the welded work material.

Milling Operations

In milling operations, the same phenomena is true as far as buildup is concerned. It is much more evident to the eye, in that it can be plainly seen where the chip adheres to the cutting tool and is carried around again to where the cutter tooth re-enters. Many gadgets have been devised to remove this chip, but with limited effect. In some places simple brushing, or blowing off with airblasts may be practical. For other applications, more drastic methods may have to be tried. Carbides for tapping of HT alloys at this date have not been found to have a great deal of practicality.

For most of the following data, cutting fluids definitely are recommended. Both water-base and sulphur-base oils are used. Where buildup is encountered, sulphur or mineral oils are suggested to reduce the welding of chip-to-carbide. Where tool failure by abrasion is a factor, a water-base coolant will dissipate heat. A machinability computer often is valuable in solving machining feeds and speeds for the HT alloys. It provides latitude in studying tool life or production rates with a change of one or more, or all of the machining variables. The Carboloy machinability computer is an electric analog unit which considers the effect of 19 machining variables, i.e., tool geometry, feed, speed, depth of cut, work material microstructure, hardness, and tool-life.

Tool Geometries

Positive rake tools usually are best suited for the HT alloys with side rake angles up to 20 deg. Where the turning operation does not necessitate a form or shoulder there is a recommendation for large lead angles, about 45 deg. Minimum nose radii will reduce the possibility of work-hardening. Clearance angles on both side-cutting edge angle and end-cutting edge angle of 6 or 7 deg will suffice. A maximum

SUGGESTED MACHINING PRACTICES FOR HIGH TEMPERATURE ALLOYS

	TURNING							MILLING				DRILLING		
	Speed, Feed, Depth Range			Carboloy Cemented Carbide Grade Selector				Speed, Feed, Depth Range		Grade Selector			Speed, Feed Rates	
Feed →	0.015-0.020	0.010-0.015	0.005-0.010				Feed Tooth →	0.006-0.010	0.003-0.006			Feed/Rev. HSS Drills →	1/8-1/2 diameter drills 0.002-0.006	
Depth →	3/32-1/4	3/64-1/8	1/64-3/64	Rough	Semi-Rough	Finish	Depth →	1/8-1/4	1/32-1/8	Rough	Finish	Feed/Rev. Cold Point[7] Drills →	0.0003-0.0005 for each 1/16 of drill diameter	
Work Material ↓	S. F. P. M. ↓							S. F. P. M. ↓					S. F. P. M. HSS Drills ↓	S. F. P. M. Carbide-Tip Drills
Rene' 41[1]	30-40	35-60	60-100	44A	883	999-905		40-60	60-100	44A	883		4-8	
J-1300 (M-308)	60-80	80-100	100-125	370	350	350-330		50-75	70-110	370-78B	350-78			
J-1500 (M-252)			75-125						60-100				8-12	
J-1570	30-50	40-75						40-60						
J-1630			75-100						40-75					
A-286[2]	50-75	60-100	100-150	44A	883	999-905		50-75	50-100	44A	883		10-15	100-125
S-816[2]	30-50	45-65	60-80					40-60	60-100					
Waspaloy[3]		40-75	75-125										8-12	
Udimet 500[4]	50-75	70-80	80-100					50-75	50-100					
Inconel X[5]	30-40	35-50	60-90					40-70	40-90				10-15	
Timken 16-25-6[6]	50-75	75-100	100-175	370	350	350-330		50-75	50-100	370-78B	350-78			
300 Stainless Series	140-275	140-325	150-400	44A	883	905-999		150-250	250-350	44A	883		20-30	
Nimonic Alloys[5]	30-40	35-50	60-90					40-70	60-100				10-20	
Titanium (pure)	100-200	175-275	300-450			999-905		80-125	125-200				60-90	
Titanium (alloy)	50-100	100-175	150-300					40-80	70-100				50-80	

[1] Rene' 41; General Electric Co.
[2] A-286 and S-816; Allegheny Ludlum Steel Corp.
[3] Waspaloy; Pratt & Whitney Div., United Aircraft Corp.
[4] Udimet; Utica Metals Div., Kelsey Hayes Co.
[5] Inconel and Nimonic; International Nickel Co., Inc.
[6] Timken; Timken Roller Bearing Co.
[7] Cold Point; Mossberg, Inc.
[8] Based on limited tests.

HT alloys . . .

continued

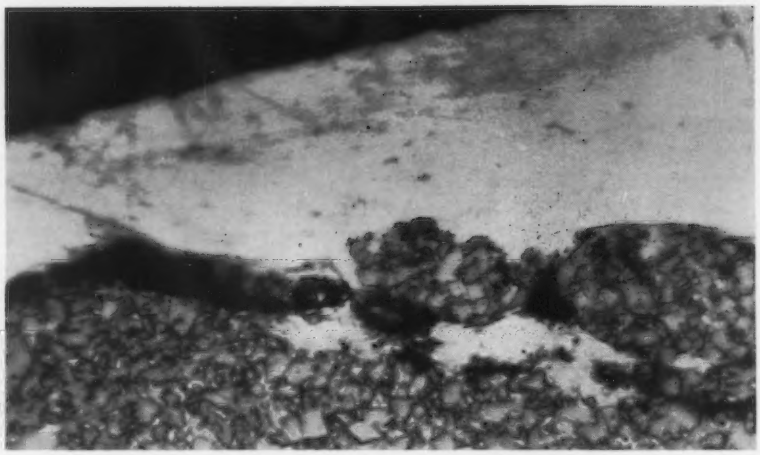

Fig. 1. Photomicrograph indicates how particles are dislodged from the basic carbide. The work material is interlocked with the tungsten particles of the tool.

depth of cut should be taken to allow the tool to get under a work-hardened surface. On thin-walled sections, a combination of positive side and back rakes should be used.

This does not rule out negative rake tools. In cases where maximum production is essential and there is willingness to sacrifice tool life caused by restricted chip flow with welding and pullout, negative rake tools can be used. Another practical reason for adopting the negative rake type of tool is that on the mechanical negative rake toolholders for square inserts there are eight cutting edges, as opposed to the four edges of the positive rake toolholders.

In milling applications it should be realized that the reason for some cutting edge failures is the welding of chips to the tool. To cut this possibility to the minimum these geometries are recommended:

Radial rake	—10 deg
Axial rake	15 deg
True rake	9 deg

Peripheral cutting angle (from cutter axis) 65 deg.
Peripheral cutting edge angle relief 5 deg.
Face cutting edge angle 5 deg.
Face cutting edge angle relief 5 deg.
Chamfer or corner angle 0 deg.

Drilling Operations

For drilling with both carbide and high-speed drills the most successful point angle will range from 118 to 135 deg. For these HT alloys the most common practice has been to use a high speed steel crankshaft-point drill with a polished fast spiral, with clearance angle between 10 and 15 deg. Some rather spectacular results have been obtained with the "Cold Point" drill recently announced by Mossberg, Incorporated, of Cincinnati. The drill design basically is clean and simple and its success may be attributed to two features: a large supply of high pressure coolant directly applied to the work and the geometry of the drill tip. Speed of this drill approaches 200 sfpm in drilling some of the refractory HT alloys.

Carbide has not been successful in HT alloy tapping operation; here, highspeed steels are most practical. Either two- or three-flute spiral point taps can be used. It is strongly urged that the crest of the threads be relieved to reduce torque applied to the tap to assist in reducing breakage. A hook angle of 7 deg is usually best.

In any machining operation it cannot be over emphasized that rigidity of tool, toolholder, and the work is absolutely essential. Mechanical toolholders are recommended with their rugged design of the heat-treated shank and the carbide seat, providing maximum support for the cutting insert. Disposable insert toolholders make it possible to reduce downtime with faster insert changing for the shorter tool life obtained throughout the higher-speed cutting ranges.

◆

Eight Thoughts for Machining High Temp Alloys

1. *Keep the speed down.*
2. *Hold the work rigid.*
3. *Hold the tool rigid.*
4. *Keep tool overhang to a minimum.*
5. *Use coolant wherever possible.*
6. *Hone the cutting edge slightly.*
7. *Don't use chip breakers, but a chip curler (two or three curls is best).*
8. *And don't expect miracles . . . at least not right away.*

A REPRINT
of this article can be obtained by writing on company letterhead to
The Editor
AIRCRAFT and MISSILES MANUFACTURING
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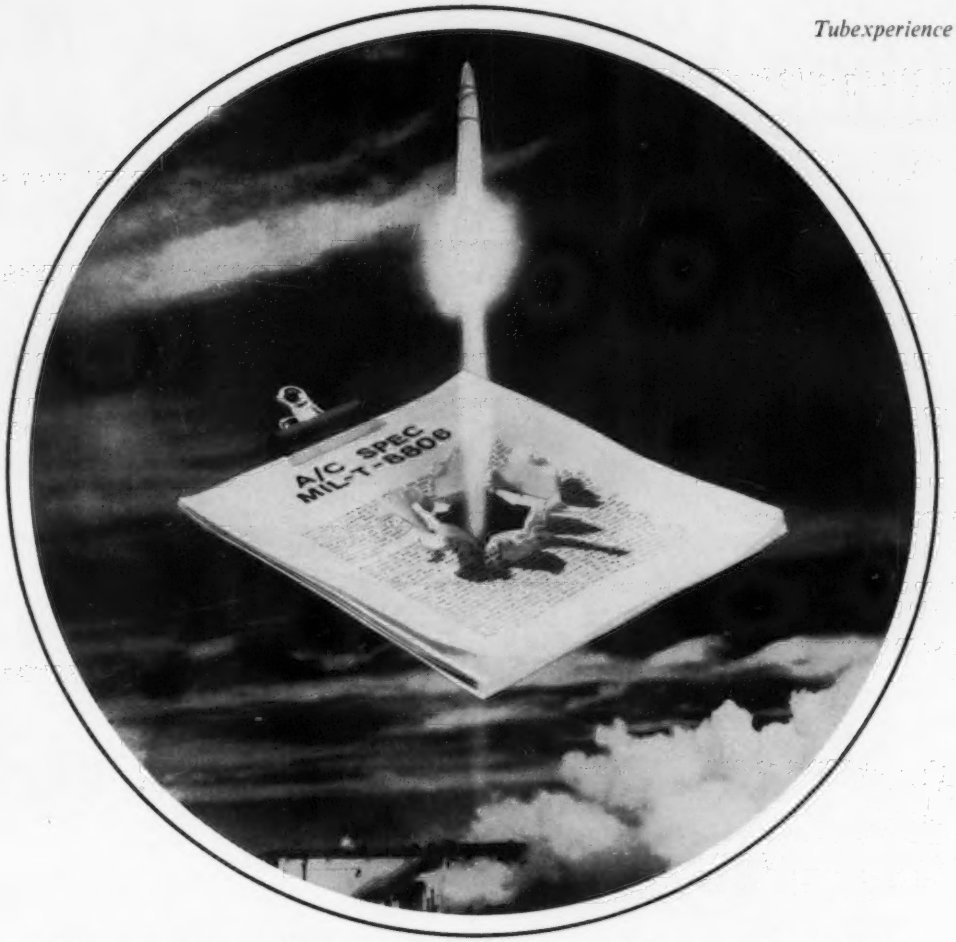
Tubexperience in action



How Superior Breaks the Spec Barrier in Stainless Hydraulic Tubing

Just meeting specifications isn't enough when you are producing stainless steel aircraft hydraulic tubing. More and more customers are asking for and getting "above normal specification" tubing from us, even though we now produce to 18 current MIL, AMS and AN Specifications.

Here are just a few of the *extras* requested by Superior customers in recent orders:

EXTRA LOW DEFECT LEVEL. We satisfied requirements by special production, verified by Eddy current inspection, the tubing being below .065 in. wall.

SPECIAL SPRING-BACK CHARACTERISTICS. Customer's requirements were met by producing the tubing to limited cold-worked temper range.

RESTRICTED MICROINCH FINISH LIMITS. Special drawing procedures and surface roughness inspection were used to achieve the finish required by the customer.

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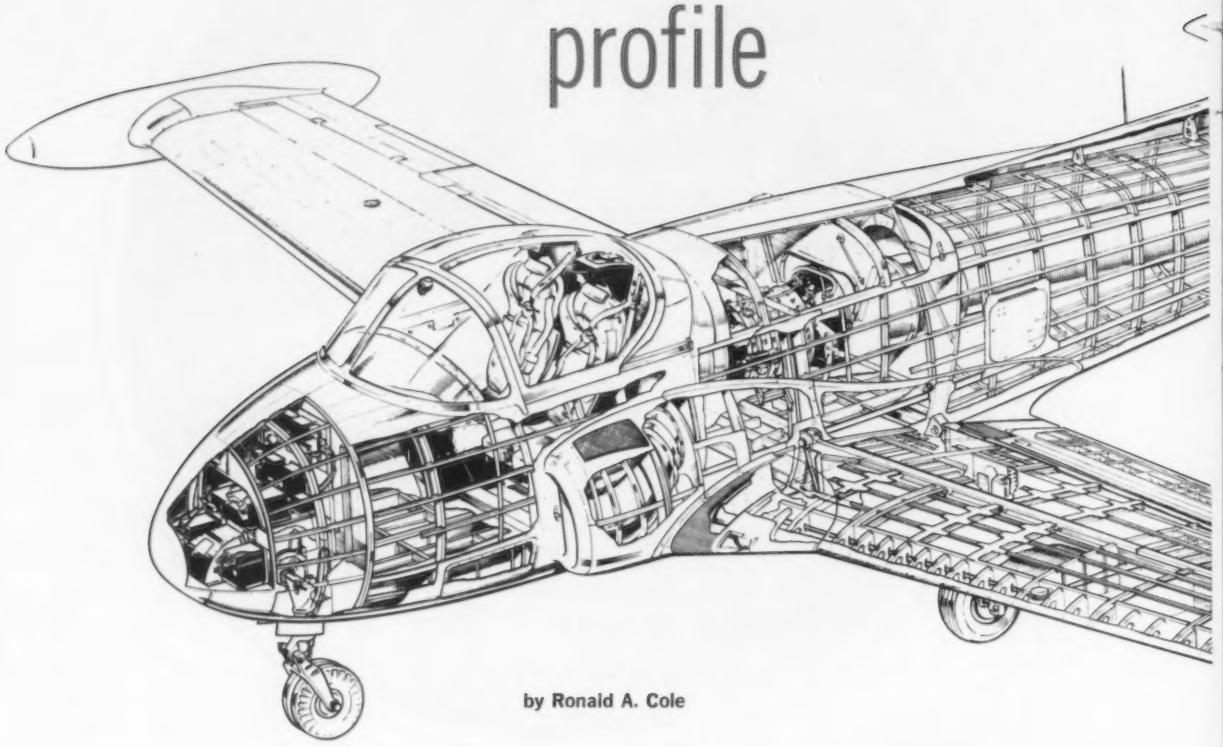
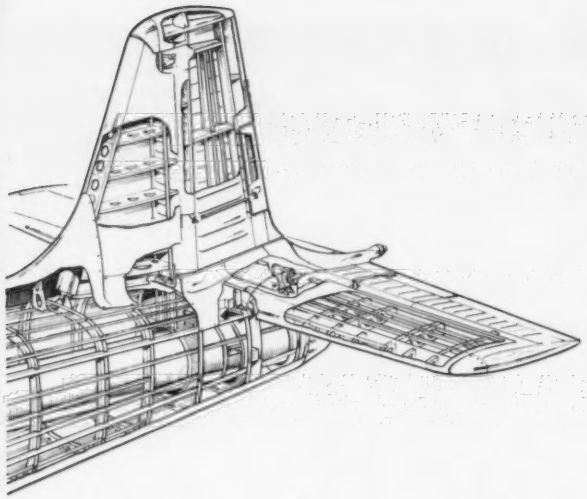
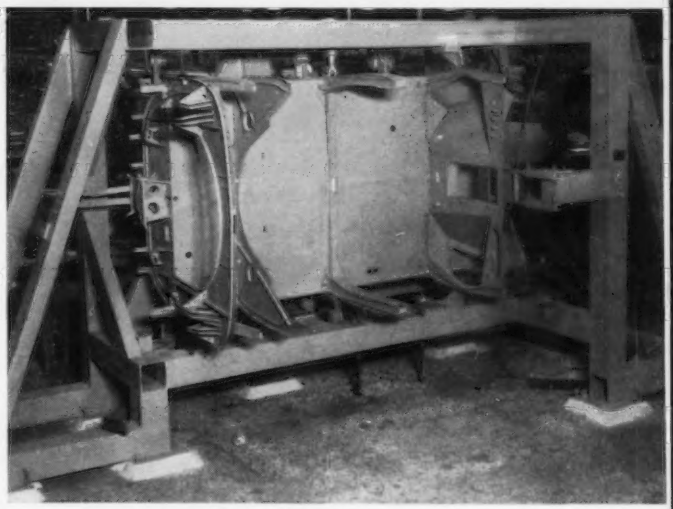
Hunting jet Provost profile



by Ronald A. Cole

The Hunting Jet Provost is a straightforward, all-metal, serviceable basic trainer; it is presently entering RAF service, to be used in a two-stage, all-jet flight-training program. Its design centers upon simple yet rugged systems, paralleling those on operational aircraft. Two side-by-side, ejection seats are provided with good visibility over the stubby nose section. Including the wing-tip tanks, a total of eight fuel cells are used, giving the aircraft a capacity of 236 imperial gallons; this allows a flight endurance of about 2½ hr. It is powered by the Armstrong Siddeley Viper turbine which develops a 1750-lb static thrust at 13,800 rpm. Although the Provost is capable of speeds up to Mach 0.8, it is designed to give good performance also at about 200 mph. The leading-edge radius has been made progressively sharper toward the wing tips to get the correct relationship between stall and spin characteristics; the basic wing airfoil is NACA 23015 at the root, and 4412 at the tip. Since the basic design of the Jet Provost was evolved from its piston-engine predecessor, many of the components are common to both versions. As a result cost per aircraft has been kept down to approximately $56,000. The wing-tip tanks shown are non-jettisonable. They are made of fiber glass, and carry 50 gallons of fuel pressurized to 2 psi. During low-speed flight and on the ground, air for fuel-system pressurization is tapped off the engine compressor. During normal operation, ram air is taken from a small inlet. Tank supercharging is part of the fuel-feed system, and is assisted by a booster pump fitted to a collector tank. The tank is located below the engine deck, on the centerline of the aircraft. This arrangement incorporates a proportioning device which insures that equal quantities of fuel are drawn from the tip tanks. Between the collector tank and the engine there is a recuperator, pressurized by the engine compressor, which allows 30 sec of inverted flight at maximum engine rpm and low altitude.





▲

The engine bay is erected on its side to give access to the top and bottom of the flooring. The front bulkhead with the air inlets can be seen at right, as well as the aft fireproof bulkhead with the V-shaped cut. This cut will accommodate the tailpipe. About half way along this bay can be seen the main-spar continuation. The floor is sloped down on either side of the airplane centerline to facilitate fluid drainage.

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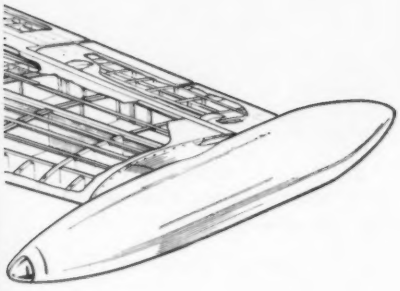


Hunting jet Provost profile . . .

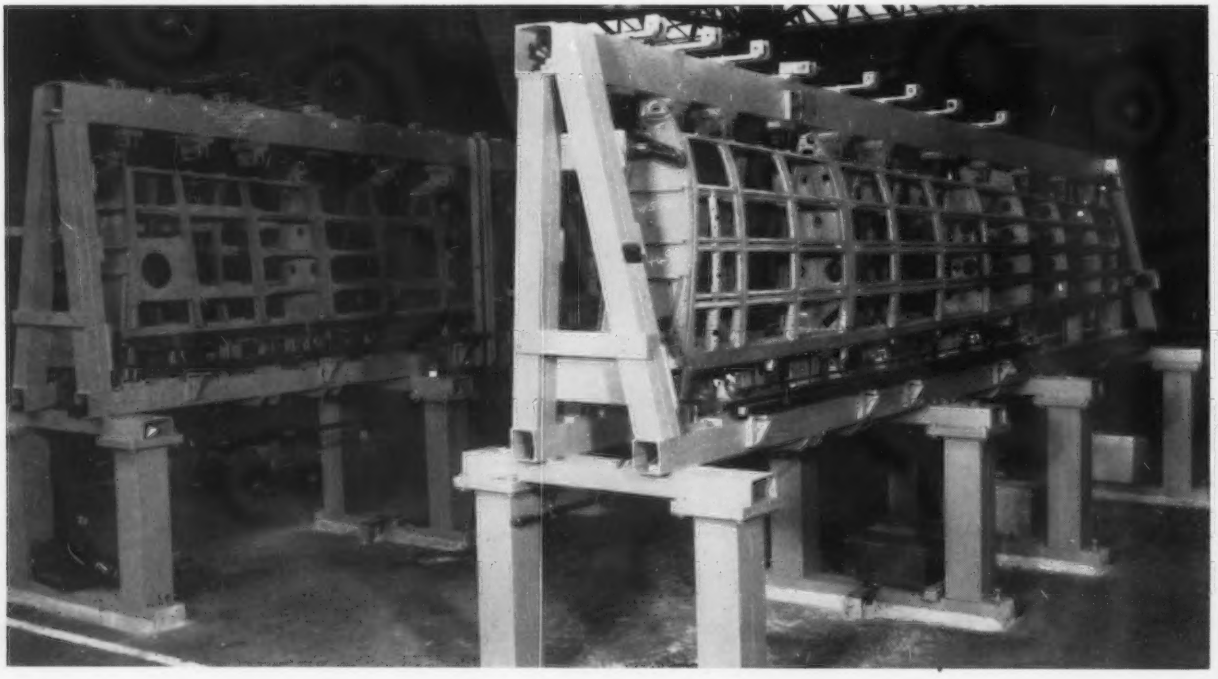
continued

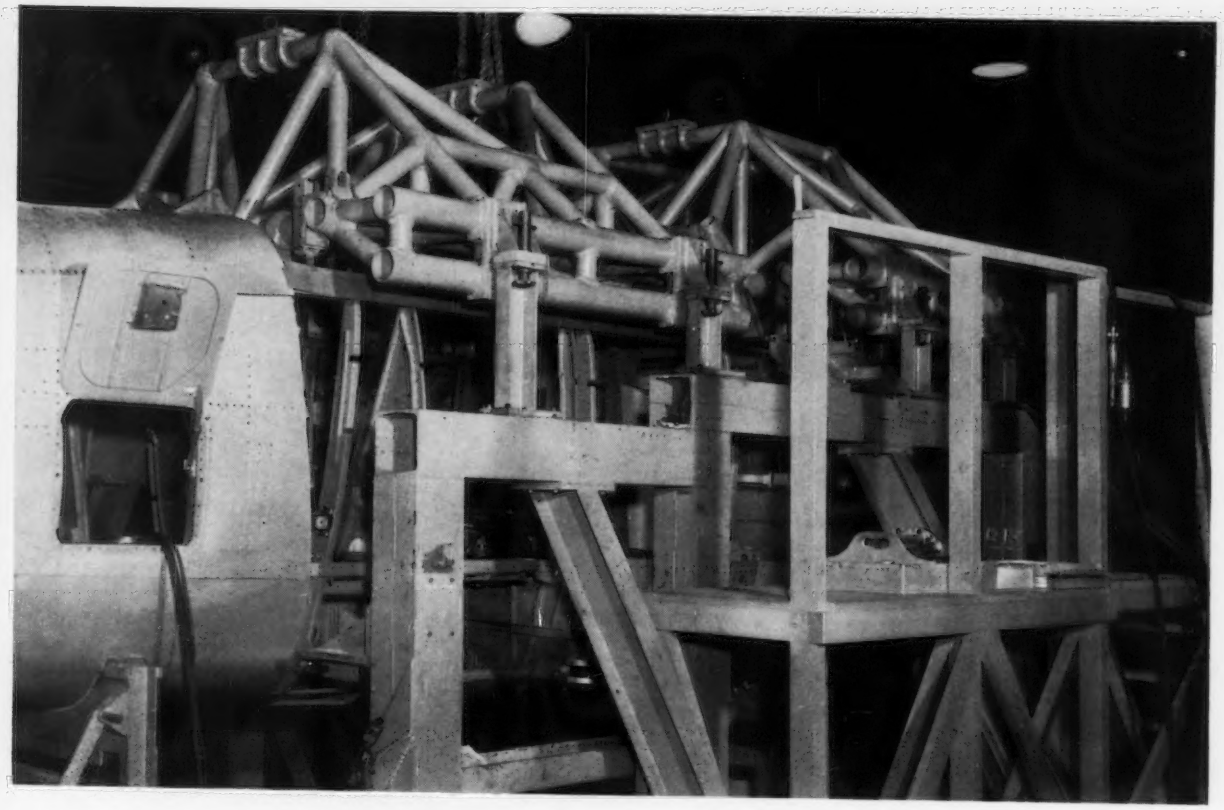
▲ Large, removable, dorsal doors and panels facilitate access to engine bay. For removal of the engine, the door hinge-strap and cross members are removed. Once the tailpipe is disconnected, the engine may be lifted out.

Cockpit section and engine bay are seen here during mating with fuselage aft section. Truss-type locating jigs are in position for engine-bay doors and canopy rails. These trusses are made of glass fiber tubes. These "plastic" jigs are positioned on the main assembly jig built up from the floor. ▶

Wing leading-edge section assembly is effected in vertical fixtures. Two tank-bays extend outboard to about mid-span position. Each lattice of frame ribs and spanwise stiffeners, for the two tank bays, is previously assembled and covered with a routed grid-plate in a separate jig. The grid plate can be seen at left.

▼





Aft fuselage top and bottom assemblies (canoes) are joined by the addition of side panels. Joining takes place through skin overlaps, shown in process here.

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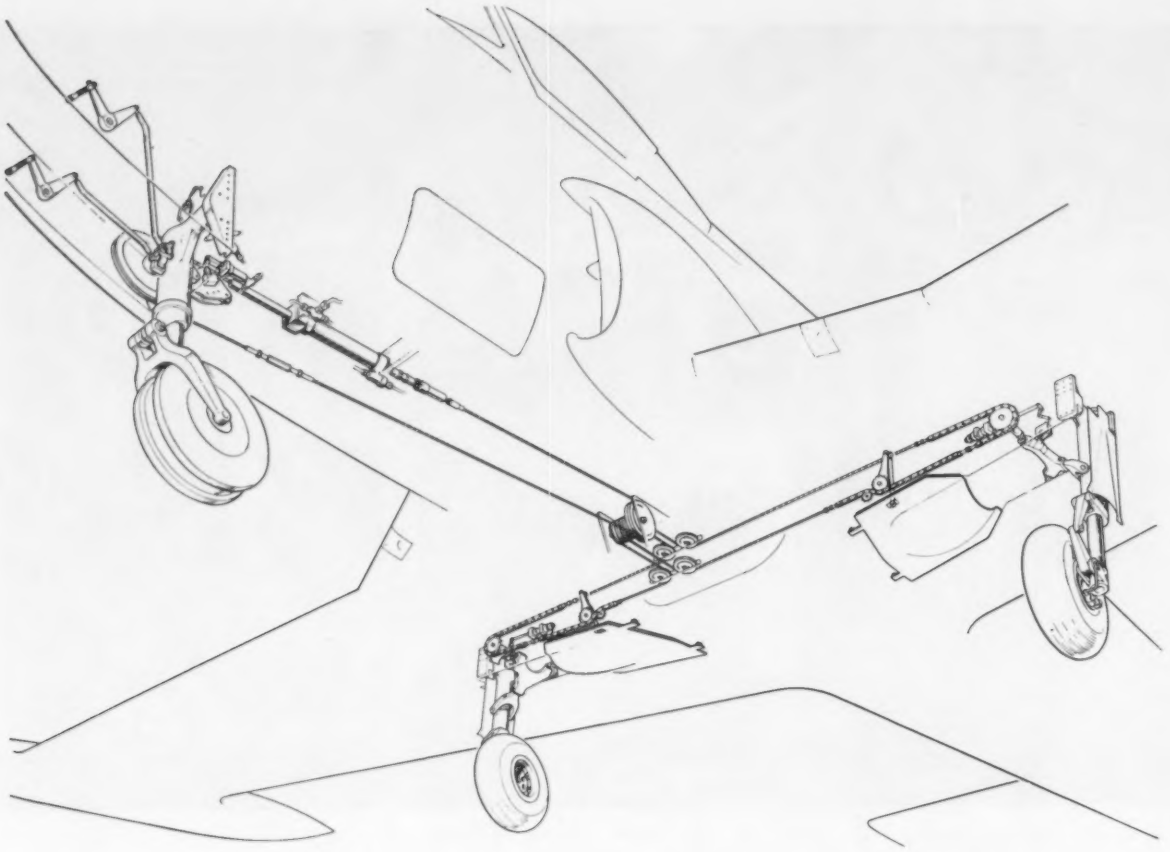
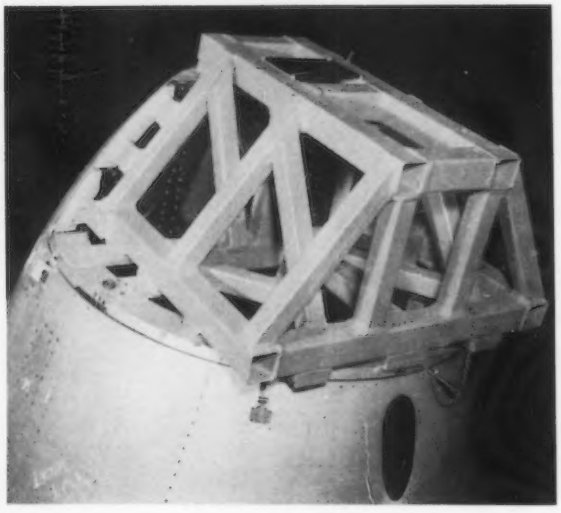


Hunting jet Provost profile . . . continued

▲

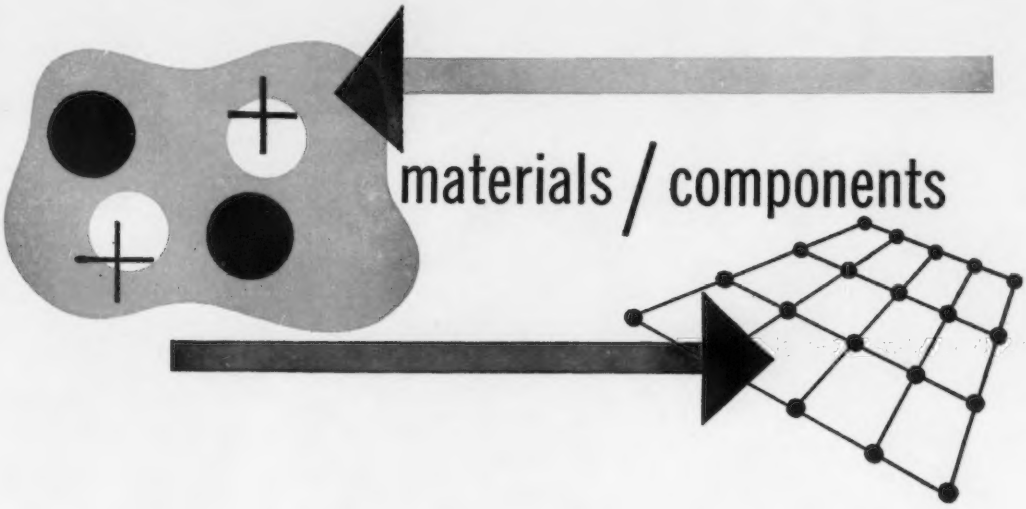
In keeping with the general simplicity of design, the tricycle landing gear is operated by a single actuating cylinder located below the cockpit. A continuous cable attached to one end of the actuator rod runs forward, then over a large pulley on the nose wheel strut, and forms a completed loop over a pulley and drum in the wing center section. The drum, in turn, actuates each half of the landing gear and wheel-well doors through two separate loops of cable. All three doors close when the wheels are down, to keep dirt and mud out.



◀

Another type of glass fiber jig is shown made of square tubing. This jig is used for checking the nose compartment door fittings: it is light enough to be lifted by one hand. In addition to lightness, another advantage of glass fiber jigs is their imperviousness to temperature changes. The major disadvantage at present is that the cost of glass fiber tubing in Europe is about three times that of steel tubing.

✦



GRAPHITE IN FLEXIBLE TEXTILE FORM

New refractory fabric called graphite cloth may find use as reinforcing agent for plastics and other materials used at high temperatures. They reportedly have excellent potential for materials subject to thermal cycling, and can impart conductivity to some non-conductors.

New process converts fibers and fabrics directly to graphite by electrically heating them to about 5400°F.

Thermo-chemical conversion changes crystalline structure of the material to that of graphite with a purity above 99.9 per cent.

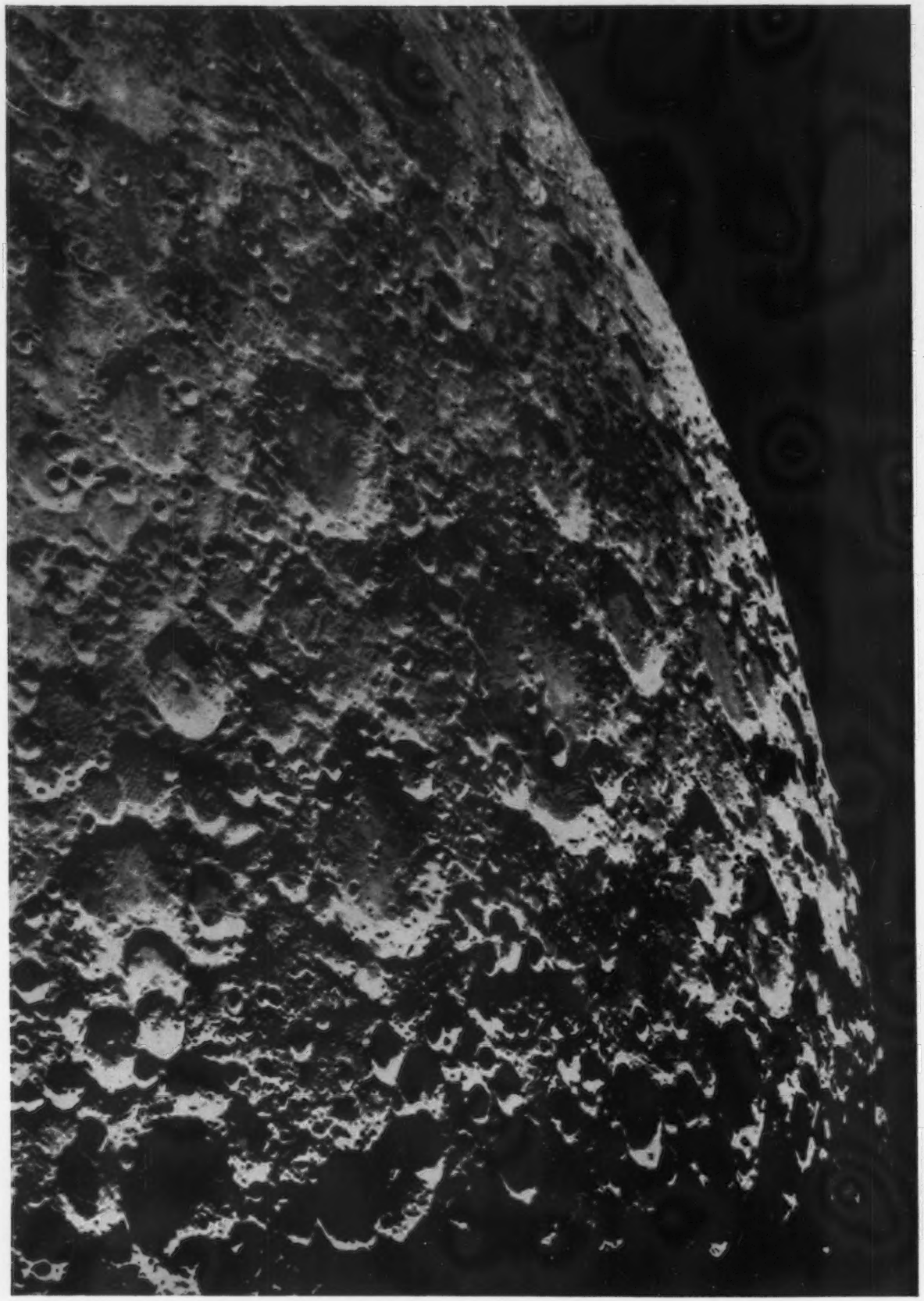
One of the most promising immediate uses of the new refractory fabric is as a reinforcing material for plastics in production of high temperature materials for the astronautic age. Illustration shows an experimental air foil section being prepared for tests.

Any textile form—yarns, braids, woven or knit fabrics—can be converted. The graphite fabric can be plated, or it can be laminated. It can be used to impart electrical and thermal conductivity to non-conducting materials.

Individual yarns of graphite have shown tensile strengths as high as 15,000 psi. The real density of the fiber is comparable to manufactured graphite.

National Carbon Co.
Div. of Union Carbide Corp.

Circle 54 on postcard for more data



"THE MILITARY REQUIREMENTS FOR MOON BASE"
This is the title of one of four major proposals developed within the past 12 months by Martin for the military and astroscientific branches of our Government. The importance of this proposal is two-fold: the inevitability of an actual moon base program by this country within the next 5 years, and; we could and can undertake such a project now — not in theory but in "hard" engineering design. In preparation for that inevitability, Martin already has built the capability for it. One important step was the creation of the Space Flight Division*, which is now directing Phase 1 of Project DYNA-SOAR.

*The Space Flight Division is one of the 7 divisions of Martin

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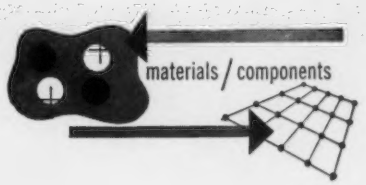

FOAMED METALS MAY AID IN ENGINE DESIGN

Foamed metal, called F-alloy, is nine times lighter than solid metal. It is intended to promote lighter, more efficient engines for recoverable air-breathing boost units, vertical

take off systems, and hypersonic applications.

General Electric Co.

Circle 57 on postcard for more data

2-DIMENSIONAL RESISTORS MATCH STRIPLINE CIRCUIT

Stripline Resistors are a new concept in a two dimensional strip resistor. The base is a thin film of specially selected natural mica. The resistance film is an alloy of pure metals, approximately 50 millionths in. thick and sealed with a micro-thin coating of Quartz. Fired silver terminations can be supplied for dc connection of the resistor to the copper center conductor of the Microstrip or Stripline circuit.

Filmholm Corp.

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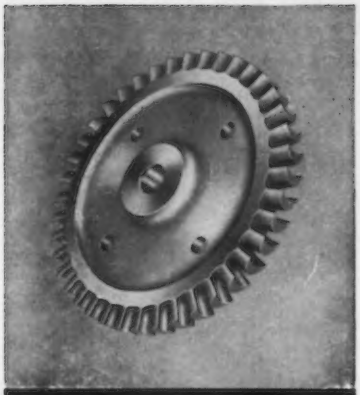
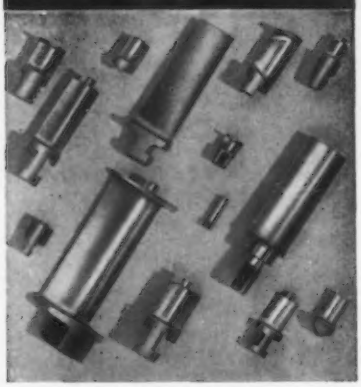


• wheels
• blades
• buckets

Schellens-True Corp.



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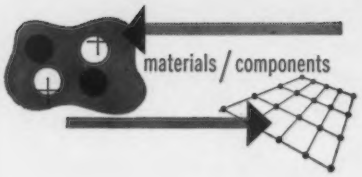
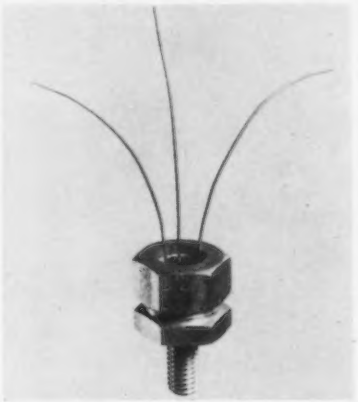
Circle 38 on Inquiry Card, page 83



TRANSISTOR HEAT SINK IS STUD MOUNTED

Stud mounted heat sink for medium power transistors provides a practical means of heat sinking transistors in the JETEC 30 round welded packages.

The 1101-A heat sink can be attached to the transistor by the user. Firmly tightening the gland nut provides a good



thermal and mechanical contact between the transistor and the heat sink. Heat dissipated in the transistor is conducted to the chassis through the 10-32 stud.

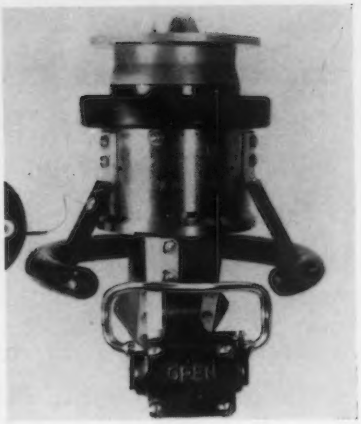
Jadaro Machine Prods.

Circle 56 on postcard for more data

H_2O_2 ADAPTER AND NOZZLE HAS SAFETY FEATURES

A self-sealing, high-flow-rate hydrogen peroxide nozzle and adapter for servicing aircraft or missiles is now available.

For safety, the nozzle is manually locked to the adapter before the internal valves are actuated and, collaterally, the internal valves must be completely closed before disengagement. Another important feature of the nozzle is that all working parts are fitted externally and do not come in contact with the oxidizer.



The adapter is available in sizes from 1½ to 6 in.

Flight Refueling Inc.

Circle 51 on postcard for more data

BALL VALVES EXHIBIT MISSILE POTENTIAL

An extensive line of ball valves is now available for missile in-flight and ground support applications.

Ball valves are used with standard fuels and oils, high energy fuels, oxidizers coolants, and cryogenics. They combine simple design and rugged construction.

When functioning as drain, selector, fill and flushing valves, this ball type design can be actuated by manual, mechanical or electrical means.

Koehler Aircraft Prods. Co. Sales Promotion Dept.

Circle 61 on postcard for more data

Circle 18 on Inquiry Card, page 83 ⟶

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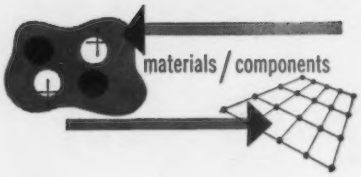
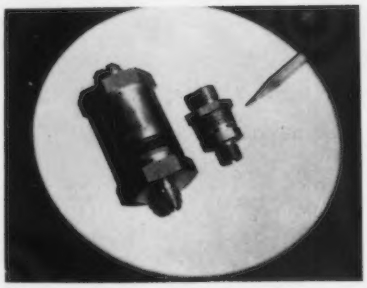
Sales Office
600 Sixteenth St.
Oakland 12, Calif.





BONDING AGENT R-313 UNAFFECTED BY "SKYDROL"

Helix Bonding Agent R-313 has proved to be unaffected by "Skydrol" hydraulic fluid as well as jet fuels and other corrosive liquids.

Bonding name plates to hydraulic line fillings is one of many applications for this epoxy bonding agent. The R-313 formula has also bonded Plexiglas to metal, glass to glass, glass to metal, and metal to metal.

H. Biggs Co.

Circle 52 on postcard for more data

ROCKET-EJECTION SEAT AVAILABLE TO INDUSTRY

North American Aviation's rocket-catapult flight and ground level ejection seat system has been officially accepted by the Navy's Bureau of Aeronautics.

The system will be made available for use by other aircraft manufacturers.

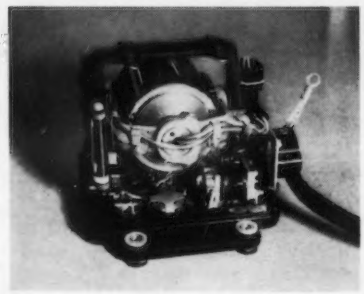
North American Aviation

Circle 59 on postcard for more data

NEW RATE GYRO HAS IMPROVED DAMPER

A new gyroscope for indicating or controlling attitude range of change for aircraft or missiles has been developed. The

new unit incorporates an advanced damper permitting it to be used in rugged environments.



A wide selection of turning rates, potentiometer resistances, and damping ratios is available.

Weighing about 1.7 lb, the gyro occupies about 3.5 cu in. Its ambient temperature range is —65 to 165°F.

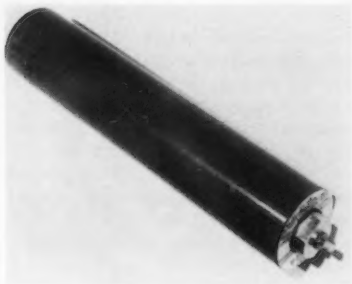
Minneapolis-Honeywell Regulator Co.

Circle 55 on postcard for more data

PISTON ACCUMULATOR HAS LEAKPROOF DESIGN

A piston accumulator, featuring a design which assures long seal life and no air or oil leakage, was recently introduced.

The unit incorporates a free piston with three "O" ring seals. Any oil or air trapped between two given seals is automatically discharged to its respective chamber during each piston stroke.



The end caps use the same size "O" ring seals as the piston, thus requiring only one size of seal to be stocked for maintenance, and reducing spare part inventory.

Narda Hydraulics Corp.

Circle 50 on postcard for more data

TEFLON TAPES

Four grades of Teflon tape feature excellent electrical properties, resistance to all common chemicals, and a low coefficient of friction. The tapes are designed primarily for high temperature and high frequency wire and cable insulation.

Continental Diamond Fibre Corp.

Circle 60 on postcard for more data

AIRBORNE COMPRESSION

The development of a contaminant-free, high-pressure compressor for airborne applications has been announced. Designed to deliver 0.2 cfm with a compression ratio of 20 to 1, the new diaphragm-type device has been successfully applied to liquid nitrogen production.

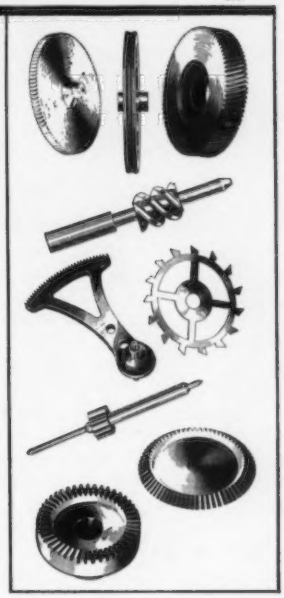
Stratos Div.
Fairchild Engine & Airplane Co.

Circle 53 on postcard for more data

-GEARS

. . . to critical tolerances

2681



Aircraft and Missile men • • • • your precision gear problems can be solved • • simply • • by application of the Hamilton **PRECISION** Gear Hobbing Machine

• • • an **AMERICAN** machine • • • • designed and built especially for work like yours. Write • • • now • • • for our free literature packet No. GH 840.

Hamilton

PRECISION SMALL-GEAR HOBBING MACHINE

THESE ARE REPRESENTATIVE USERS OF HAMILTON GEAR HOBBING EQUIPMENT

AiResearch Manufacturing Co. • *Duncan Electric Co.* • Bendix Aviation Corp. • *Victor Adding Machine Co.* • Lear, Co. *Minneapolis-Honeywell Regulator Co.* • Geophysical Machine Works • *Hughes Aircraft Co.* • Westinghouse Electric Corp. • *Rockwell Meters, Inc.* • Borg Products Division • *Herschede Hall Clock Co.* • U. S. Navy Electronics Laboratory • *Redstone Arsenal* • Smallwood & Son Machine Co. • *Link Aviation, Inc.* • Bell Aircraft • *General Mills* • Elgin National Watch Co. • *U. S. Naval Gun Factory* • Grimes Manufacturing Co. • *Texas Instruments, Inc.* • McDonnell Aircraft Co. • *American Machine & Metals* • Stromberg-Carlson Co. • *Hamilton Standard* • U. S. Gauge Co. • *Western Gear Works* • Schlumberger Well Surveying Corp. • *Douglas Aircraft.*

THE HAMILTON TOOL COMPANY • 882 SOUTH NINTH STREET • HAMILTON, OHIO

AIRCRAFT & MISSILES MANUFACTURING DIGEST OF RECENTLY PUBLISHED TECHNICAL MATERIAL

producibility REVIEW

PRODUCTION

BUTT WELDING PROVES OUT FOR THIN GAGES, G. C. Close. *Space/Aero.* (April, 1959), 3 pp. Production setup, applications, and mechanical properties obtained from tests are given.

ELECTRONIC MILLERS SPEED AIRFOIL MACHINING. G. H. DeGroat. *Amer. Mach.* (March 9, 1959) 3 pp. Description of equipment and methods used at Solar for the production of compressor blades and turbine buckets for engines.

PREDICTION IN NEW METAL JOINING PROCESSES. J. J. Chyle. *SAE paper #52S* (April 3, 1959) 36 pp. Under the three broad categories of pressure welding, fusion welding, and brazing, the recent ramifications of process are discussed. Description of equipment given, together with applications.

STEEL ROUTING — DEVELOPMENT OF HIGH-RATE METAL-REMOVAL TECHNIQUE. *Acft. Prod.* (March, 1959) 4 pp. Ferrand Luttmer system applies CO_2 coolant through router-head spindle, and uses tungsten-carbide cutters to rout steel parts.

THE MACHINING OF ULTRA STRENGTH ALLOYS. J. Maranchik, Jr., J. V. Gould and P. R. Arzt. *SAE paper #43R* (April 3, 1959) 39 pp. Results of machinability studies reported, as made on martensitic low-alloy steels, hot-work die-steels, precipitation-hardening stainless-steels, and austenitic stainless-steels.

PROGRESS IN SPACE-AGE MATERIALS FABRICATION. L. E. Laux and C. S. Hill. *SAE paper #43S* (April 3, 1959) 22 pp. The experience of the Martin Co. cited, with high-strength, heat-resistant materials. Case histories are given on the production of several missile components, and related problems.

GOVERNMENT RELEASES

PROCUREMENT HANDBOOK. 271 pp, published by the General Services Administration, gives detailed economic and efficient procurement procedures, and related supply management services. A 70-page appendix contains sample copies of forms used in government purchasing. (Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.; price: $1.50.)

ROCKET EXHAUST CORROSION SIMULATOR. F. B. Cramer. A 138-page report covering the methods and equipment used for studying the corrosive effects of rocket-exhaust gases upon various metal and paint-coated surfaces. (Order PB 151273 from OTS, U. S. Department of Commerce, Washington 25, D. C.; price: $2.75.)

CLEANING AND PASSIVATION OF CORROSION-RESISTING STEELS. L. Lowry and J. Thompson. A 28-page report giving a survey of typical cleaning methods for removing surface contaminants such as scale, flux, slug, metallic lubricant, and iron from the surface of corrosion-resistant steels. AISI type 200, 300, and 400 series steels were used. (Order PB 131964 from OTS, U. S. Department of Commerce, Washington 25, D. C.; price: 75 cents.)

CHEMICAL RESISTANCE AND THERMAL STABILITY OF FLUOROCARBON ELASTOMER. A. Wilson, C. B. Griffis and J. C. Montermoso. A 23-page report evaluates fluorocarbon elastomer 214, a copolymer of vinylidene fluoride and perfluoropropene, for resistance to fuels, oils, heat, and acids, including red fuming nitric acid. (Order PB 131942 from OTS, U. S. Department of Commerce, Washington 25, D. C.; price: 75 cents.)

SELECTION AND EVALUATION OF RARE AND UNUSUAL METALS FOR APPLICATION TO ADVANCED WEAPONS SYSTEMS. B. Love. A 185-page report drawn from unclassified literature discusses the abundance and distribution of rare elements, methods of recovery, reduction, and properties. Possible uses of rare earths both in metallic and non-metallic forms are considered from production and economic viewpoints. (Order PB 151311 from OTS, U. S. Department of Commerce, Washington 25, D. C.; price $3.00.)

BOOKS RECEIVED

SPACE GUIDE, V. F. Callahan, Jr., editor. *Washington Space Letter*, 1959. 173 pp. $10.00. This publication is concerned primarily with the organization and present and future activities of the National Aeronautics and Space Administration. Included are

the organization chart of NASA, personnel, biographies of key officials, and NASA advisory committees. A partial list of NASA projects is given together with a breakdown of the 1960 budget. Contracting procedures and procurement offices are listed, as well as the services, supplies and equipment purchased by NASA on a competitive basis.

FUNDAMENTALS OF ADVANCED MISSILES, by R. B. Dow. *Wiley*, 1958. 567 pp. $11.75. The definition of an "advanced missile" as treated here is as follows: an unmanned vehicle, incorporating a warhead or similar lethal components, that is jet-propelled at supersonic or higher speeds in the atmosphere and in free space under the influence of some mode of "variable" guidance and/or "fixed" control. The author has stressed the fundamental principles applicable both to ballistic and guided missiles, as well as, to space vehicles. The subject matter is treated theoretically, with examples drawn from practice. A good grounding in mathematics and calculus is assumed. Chapter headings are as follows: 1—Kinematics of flight; 2—Application of fluid mechanics to aerodynamics and propulsion; 3—Dynamics; 4—Some applications of probability and statistics; 5—Properties of microwaves; 6—Application of infrared radiation; 7—Radar; 8—Guidance; 9—Guided-missile systems.

THE AIRCRAFT YEAR BOOK, 1959. Official publication of the Aircraft Industries Assn. *American Aviation Publications*. 486 pp. $6.00. Fully illustrated annual volume gives a broad picture of the aircraft industry and its numerous activities; both civil and military phases are covered. Photographs, specifications, and 3-view drawings of planes and engines currently in production are presented. Photographs and status reports are also given on all missiles in operation, production and development. Included are also a chronology of American aviation history, official records, and a list of aviation books published in the United States in 1958.

REVIEWED IN THIS ISSUE

Periodicals and Papers

Amer. Mach. American Machinist

Acft. Prod. Aircraft Production (British)

SAE-Papers. Society of Automotive Engineers — Papers

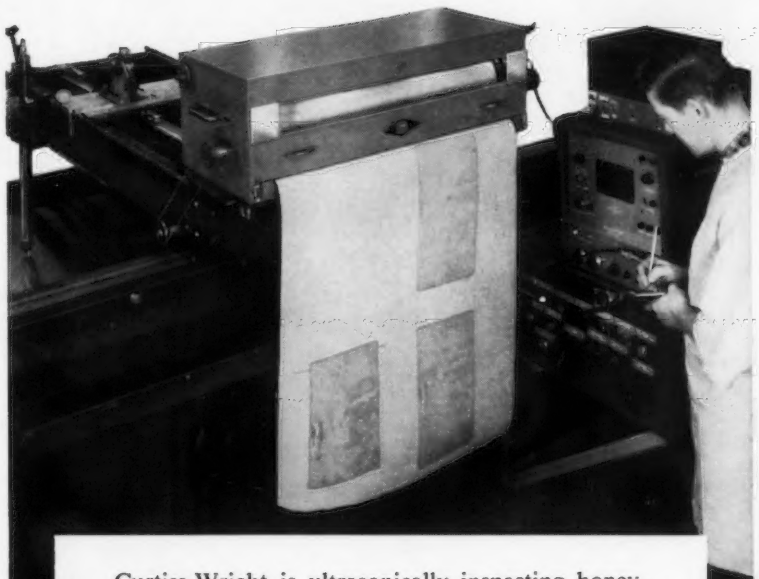
BOOKS RECEIVED

Space Guide. Washington Space Letter

Fundamentals of Advanced Missiles. Wiley

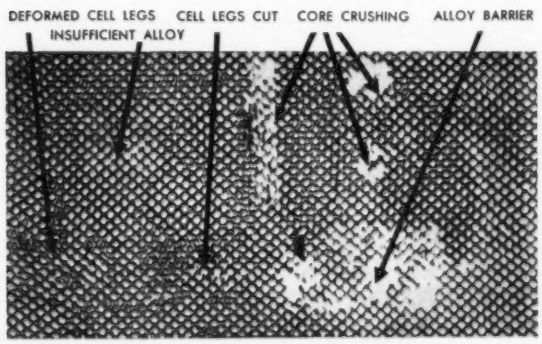
The Aircraft Yearbook 1959. American Aviation Publications

HONEYCOMB INSPECTED
ULTRASONICALLY!



Curtiss-Wright is ultrasonically inspecting honeycomb with successful results. Our technique completely scans panels up to twelve feet wide, achieves high speed and provides an instantaneous permanent record.

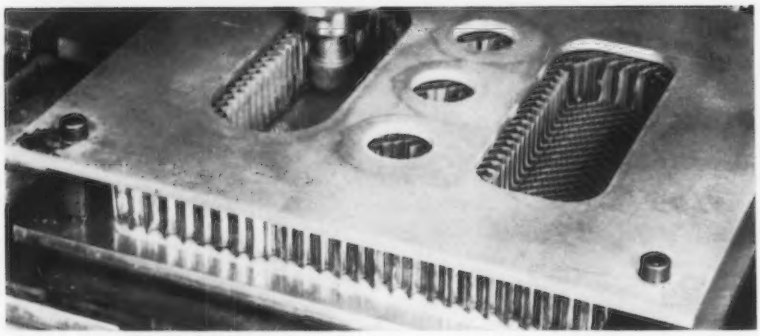
Let us help you evaluate the application of this technique to your honeycomb quality control problem. Write, wire or phone for consultation with a Curtiss-Wright engineer today.



PRINCETON DIVISION
CURTISS-WRIGHT
CORPORATION · PRINCETON, N.J.

In Canada contact CANADIAN CURTISS-WRIGHT LIMITED, 1980 SHERBROOKE STREET WEST, MONTREAL, P.Q., CANADA
In countries other than U.S.A. and Canada contact
EXPORT DIVISION, CURTISS-WRIGHT CORPORATION, 50 ROCKEFELLER PLAZA, NEW YORK 20, NEW YORK

MACHINING HONEYCOMB



A new process permits machining of complex stainless steel honeycomb contours.

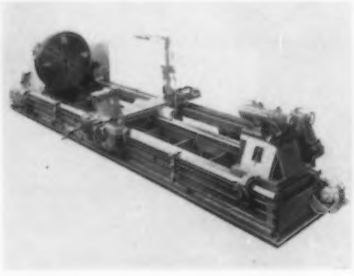
Modified tracer method, used with a special control mechanism, gives close tolerances, stress-free surfaces, operation devoid of heat checks. Process is an exclusive application of the electrolytic method of machining honeycomb.

Ekstrom, Carlson & Co.

Circle 69 on postcard for more data

LATHE LINE

Designed for the rocket, missile and allied fields as well as for use on other large parts requiring precision, the new "Space-Master" series is available in swings up to 72 in. and center distances ranging up to 50 ft.



Among features: a 16-spindle-speed headstock with lapped herringbone gears.

For thread and feed changes 60 ratios are standard. For infinitely variable speeds, the Space-Masters are available also with DC motor drive.

Sidney Machine Tool Co.

Circle 71 on postcard for more data

ULTRASONIC MACHINING

Ultrasonic machine tool does the work of 8 conventional machines on large quantities of hard and brittle materials such as germanium.

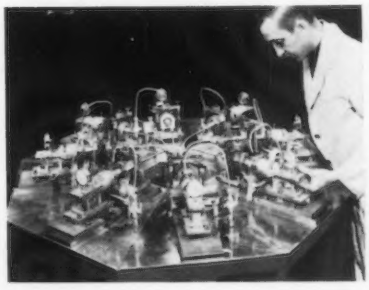
Designated the Sheffield-Cavitron 8, machine has eight horizontal machining stations arranged in a circle on a waist-high table 4½ ft in diam.

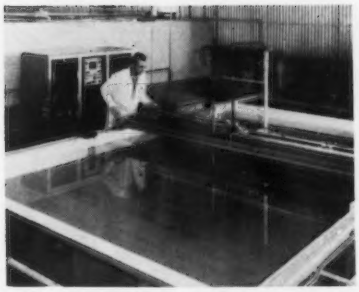
Thus, up to 8 individual and different precision operations can be conducted on as many workpieces simultaneously, or up to 8 individual operations can be performed on the same workpiece by progressing the part through each station.

Each machining station accommodates a cutting tool up to 1.08 in. in diameter, machining workpieces to .050 in. depth.

The Sheffield Corp.

Circle 72 on postcard for more data





ULTRASONIC RECORDING FOR TESTING

New ultrasonic recording system for bond testing and flaw detection results in permanent record of test information.

Excellent sensitivity and definition are obtained from tests of facing sheet to core bond in brazed honeycomb.

With the system, called Soltronics Sonafax, one to one scale recordings can be made of areas 18 in. wide and of indefinite length.

Ultrasonic Testing & Research Lab.

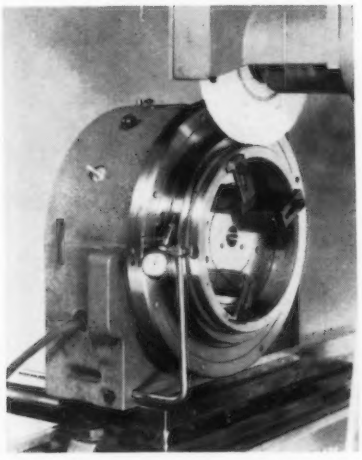
Circle 76 on postcard for more data

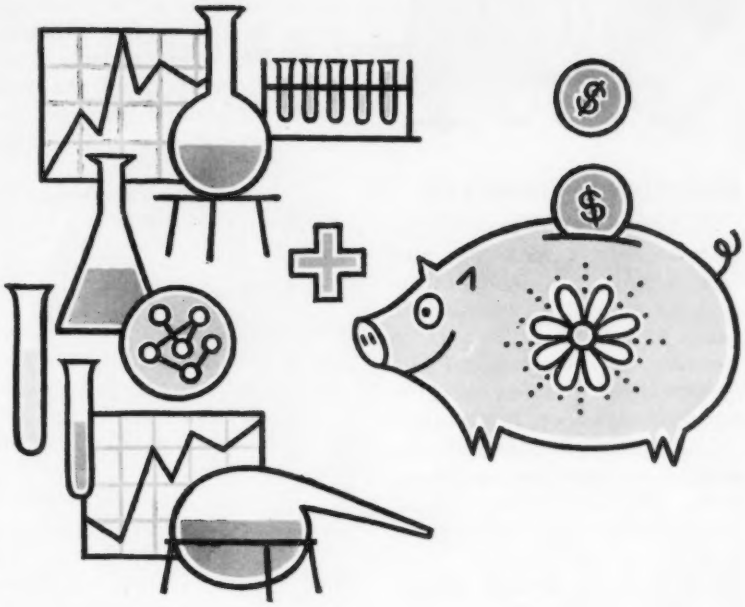
ROTO-GRIND

Motorized rotary table makes any surface grinder into a rotary grinder to grind rough or precision work. It fits on a jig grinder for grinding large rings, offset holes, radii contours.

M & M Tool & Mfg. Co.

Circle 77 on postcard for more data





All This and Savings, too!

A physical laboratory and a chemical laboratory equipped to explore, to extend, to confirm your findings on materials and processes.

Bending equipment that subdues tough metals; forms conventional or intricate shapes into accurate rings . . . the easy or the hard way.

Flash welding that joins like Damon and Pythias. Heat treating that conditions rings for strenuous, critical service.

This is King Fifth Wheel, pioneers with GE of the practical applications for Rene 41 in jet aircraft engine rings.

Our services and facilities are at your command.

King
FIFTH WHEEL CO.
P. O. BOX 759
WILKES-BARRE, PA.

RECORDING PYROMETER

Optical recording pyrometer accurately measures surface changes in temperature over an area of ⅜ in. diam in range of 1400°C to 3000°C. A recorder may be plugged into pyrometer to provide complete temperature versus time record.

Radiation-sensitive element is a high-vacuum phototube. Monochromatic light (wave-length 0.65 micron) is focused on an opaque plate. Small opening admits radiant energy to phototube.

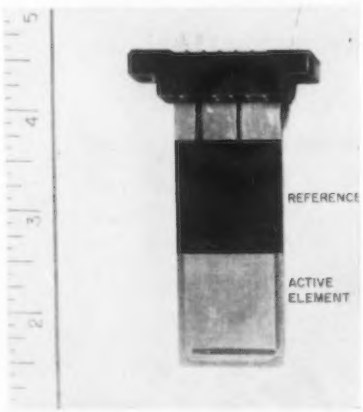
Avco Research & Advanced Development Div.

Circle 75 on postcard for more data

ENVIRONMENTAL CHANGES

Electrical resistance "probe" measures corrosion, hard-to-detect liquid and gaseous contaminants.

Probe can detect the slightest change in humidity, ozone concentration, water content in a non-aqueous liquid, or other environmental conditions



which have a tendency to attack metal.

The essential element of the probe is a vacuum-deposited film of metal, 2 to 50 millionths of an inch thick. The instrument connected to the probe can detect as little as five billionths of an inch of metal loss. Thus the concentration of the corrosive compound can be extremely small, yet quickly detected.

Crest Instrument Co.

Circle 74 on postcard for more data

DIATRONIC DIAMOND CUTTING WHEELS

Originally developed for cutting germanium and silicon, Diatronic wheels are being used by machinists and engineers for many purposes.

Wheel edges are rough, with diamond distribution uniquely uniform because of new manufacturing method. Wheels can cut tungsten carbide, glass, stainless steel honeycomb.

Navan Products Inc.

Circle 66 on postcard for more data

HEX-NUT SERIES

New hex nut series H14 are being produced for the 160,000 psi short thread NAS screws and bolts.

The low height, self-locking nuts are 20 to 40 per cent lighter than the hex nuts currently produced for 125,000 psi AN bolts.

Kaynar Mfg. Co. Inc.

Circle 68 on postcard for more data

LONG-RUN CAMERA

High film capacity 16mm motion picture camera holds 1200 ft of film and may be used for filming rocket engine tests up to 50 minutes duration. Cost is about ½ that of previous equipment.

Designated the Model 805 Fototracer, camera operates at 16, 24, 32, and 64 frames per sec. from a governor controlled heavy duty motor.

Traid Corp.

Circle 62 on postcard for more data

HOT-COLD HUMIDITY CHAMBERS

Vertical Hot-Cold-Humidity Chambers use dry ice as a refrigerant.

Front opening chambers allow operator to work at a comfortable standing height without having to lean over to work in a deep chamber.

These chambers have a range of minus 90°F to plus 240°F (to 425°F if desired) and humidity can range from 20% to 95%.

Development Engrg. Co. Inc.

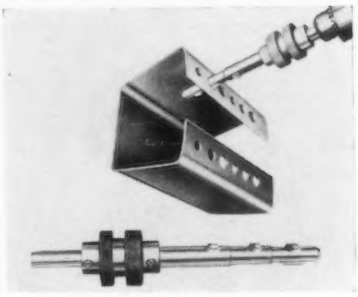
Circle 70 on postcard for more data

DEBURRING

Tool acts as portable drill-motor. It contains three separate pilot diameters and a cutter blade with three corresponding positioned cutting heads. Thus it can deburr the front and back hole faces of three different size holes without separate tool changes.

Nobur Mfg. Co.

Circle 67 on postcard for more data



CARBIDE REVERSE COUNTERSINKS

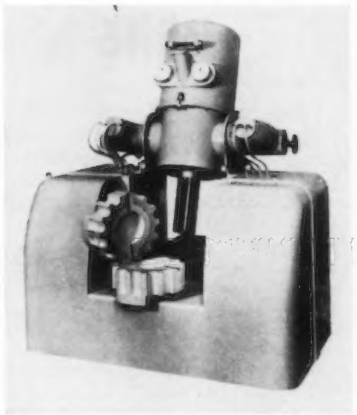
Carbide - tipped 180-C series reverse countersinks and series 190-C Spotfacers are available for use on the harder, more difficult-to-machine materials where carbide's superior cutting ability can be fully utilized.

Craig Tools Inc.

Circle 64 on postcard for more data

MELTING FURNACE MAKES UP TO 15 LB.

New vacuum and argon melting furnace can make castings up to 15 lb.



Transformers and vacuum pump are enclosed in a compact cabinet. Furnace body, complete with electrode control housings, sits across the cabinet; rotates on four rollers.

British Machines & Foundry Supplies, Ltd.

Circle 73 on postcard for more data

OSBORN® *announces:*

a new concept in power brushing tools

How **TY® BRUSHES** will significantly cut your finishing costs

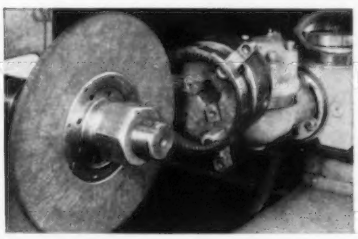
Designed for jobs *beyond the reach* of standard wire power brushes, Osborn TY® Tool Brushes are literally a new concept in finishing tools.

Where rotary files, abrasive stones or belts, tumbling and shot blasting equipment have been used—TY Brushing Methods now do many of these jobs *better . . . at significantly less cost.*

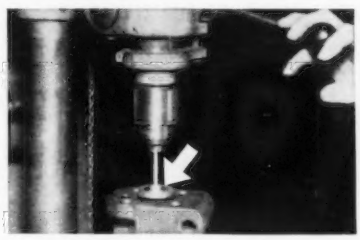
These exclusive TY Brush advantages have been proved through extensive field tests—

- *Maximum of work efficiency with minimum of pressure*
- *Greatly increased brushing action strength*
- *Positive control over area of brush contact*
- *Complete uniformity of finish*
- *Exceptionally long brushing tool life*

Osborn TY Brushes will give you a higher rate of output . . . better product quality . . . lower end-of-service cost. Write or call us today for full information. No obligation, of course. *The Osborn Manufacturing Company, Dept. AM-4, Cleveland 14, Ohio.*



Blending Gear Tooth Edges *and deburring in a single precision operation is done with Osborn TY Monitor® Brush running at 1750 rpm on Brushamatic® 3A Machine.*



Cleaning and Finishing *internal surfaces of machined castings is done with an Osborn TY Ringlock® Brush mounted on a simple drill press setup. Operation is rapid, thorough—low cost.*

Osborn Brushes

BRUSHING MACHINES
BRUSHING METHODS
POWER, PAINT AND MAINTENANCE BRUSHES
FOUNDRY PRODUCTION MACHINERY

Circle 23 on Inquiry Card, page 83

PRISM-GRATING INFRARED SPECTROPHOTOMETER

Commercial production of IR-7 prism-grating infrared spectrophotmeters is beginning. Instrument's grating operation extends throughout the 2.5-16.6 micron region.

Beckman Instruments Inc.
Circle 78 on postcard for more data

SAWTOOTH CRUSHER LINE

New perfected line of sawtooth crushers, trade-named "Laptooth," may be used to reduce titanium, zirconium, other sponge metal forms. Any friable or frangible mass may in fact be disintegrated to 1/16 in. to two in. maximum size at high rates.

Robinson Mfg. Co.
Circle 65 on postcard for more data

CONTROLLED WELDING

Critical welding temperatures are controlled automatically by H-800 motorized rheostat. This prevents undesirable metallurgical changes.

Prehead "upslope," weld time, postheat "downslope" can be programmed at optimum levels.

Harnischfeger Corp.
Circle 63 on postcard for more data

ULTRASONIC TESTER

New Audigage Model 6 weighs less than five lb.

This completely self-contained tester is used for nondestructive thickness measurement of most metals, glass, ceramics, and plastics from one side.

Portable (no external source of power is necessary), resonance gage is ideal for areas where corrosion is suspected.

Instrument is direct-reading. By setting a selector switch to one of three positions, thickness of steel, aluminum, or copper is determined automatically.

The new gage measures 9¾ x 4⅜ x 4½ in. It is powered by three standard radio-type mercury batteries designed for 70 hr continuous operation, or 2 to 4 months of normal testing.

Branson Instruments Inc.
Circle 79 on postcard for more data

TAKE THE "SHAKES" OUT OF SUPERSONIC JETS

with a TINIUS OLSEN JET STAGE BALANCING MACHINE

High accuracy . . . instant indication of both angle and amount . . . unmatched ease of operation . . . heavy duty shroud assures complete safety.

Write for full information.

TINIUS OLSEN
Testing Machine Co.
2210 Easton Rd. • Willow Grove, Pa.

Circle 24 on Inquiry Card, page 83

J & F . . . pioneer source for

REACTIVE METAL WIRE

For welding, screens, filters, fasteners, cable — .010 to 3/8 — coil or straightened — certified quality

Whether you need a few pounds or production tonnage, J&F will give you fast delivery, competitive prices, certified quality — on reactive metal wire in commercially pure form . . . in a wide selection of special alloys . . . in alloys to your own specifications.

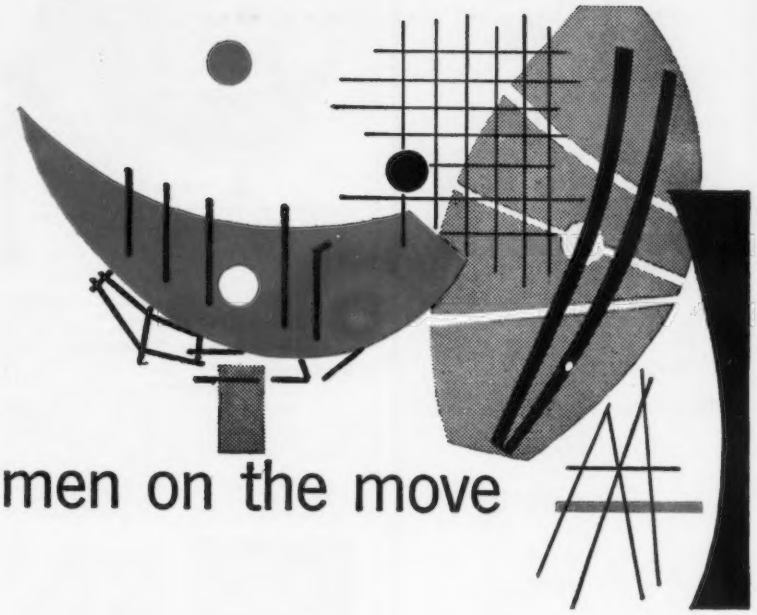
J&F wire is the product of integrated, no-compromise operation. Metallurgists who have spearheaded reactive metal development guard your order at every processing step.

Put J&F's ground-floor experience to work for you by arranging for an early meeting — or write for facilities brochure, complete wire data and prices.

J&F Johnston & Funk
METALLURGICAL CORPORATION
WEST KEMROW AVENUE, WOOSTER, OHIO

A subsidiary of Mallory-Sharon Metals Corporation

Circle 25 on Inquiry Card, page 83



men on the move

RUSSELL D. ARCHIBALD has joined Hamilton Standard, div. of United Aircraft Corp., as project engineer in the environmental controls group.

JOHN K. WETHERBEE, named chief of the Systems Engineering Div., Battelle Memorial Institute.

MARION MAXFIELD, appointed director of F-27 commercial sales for the Fairchild Engine and Airplane Corp.

RALPH L. BAYLESS, appointed director of engineering at Convair, Div. of General Dynamics.

KENNETH H. JACOBS, appointed director of engineering at Grand Central Rocket Co. EMMITT GRAHAM has been advanced to manager of a new Grand Central office at Huntsville, Ala.

LEONARD LADEN, appointed assistant to the purchasing agent; ANTHONY P. PAPPANO, named manager of purchasing administration at Goodyear Aircraft Corp. JOHN A. PITRONE has joined Goodyear in guidance engineering department as a senior engineer in the inertial and controls section. CHARLES W. CALVERT, appointed to the electrical design section of the Subroc anti-submarine missile project at Goodyear.

THOMAS J. CRELEY has joined the staff of Propellex Chemical Div., Chromalloy Corp., as project engineer.

J. S. WARSHAUER, elected president of Summers Gyroscope Co.

JAMES C. SMITH, JR., appointed executive engineer; CHARLES W. WILLIAMS, director of manufacturing operations; JOHN M. MARTIN, director of plans and programs; ROBERT C. TERBECK, director of field operations, at the Advanced Projects Organization, Chrysler Corp., Defense Group.

J. H. MANN, appointed to supervise all mechanical design engineering for the precision counter, gearhead and electro-mechanical divisions of Bowmar Instrument Corp. at its Fort Wayne facility.

JAMES M. HUGHES has been named general sales manager of titanium sales for Mallory-Sharon Metals Corp., in Niles, O.

DR. WALTER R. DORNBERGER, named director of engineering, Bell Aircraft's Niagara Frontier Div.

RICHARD H. JOHNS, named industrial products marketing manager for Autonetics, div. of North American Aviation Inc.

WILLIAM J. JACKEL becomes president of the new Albuquerque Div. of ACF Industries.

DON L. WALTER, named to the new position of vice president of the power systems group of Marquardt Aircraft Co.

DR. BERNARD LITMAN, named assistant chief engineer for research, and WEN TSING CHOW, named assistant chief engineer, missile guidance, at Arma Div., American Bosch Arma Corp.

NORMAN V. PETERSON, appointed chief of the Astronautics Group, Norair Div., Northrop Corp.

KENNETH R. BRAGG, appointed chief systems engineer, Parker Aircraft Co.

RAYMOND T. ZWACK, named manager of development engineering at Solar Aircraft Company's Des Moines Div. LYNN D. RICHARDSON, named vice president, sales.

W. GIFFORD MYERS, elected corporate vice president of sales, Lockheed Aircraft Corp. DR. LOUIS N. RIDENOUR, named vice president and general manager of Lockheed's new Electronics and Avionics Div.

V. L. JUST, designated assistant program engineer on Rocketdyne's program for the Jupiter engine.

Robert H. Johns
Autonetics

William J. Jackel
ACF Industries

Norman V. Petersen
Norair

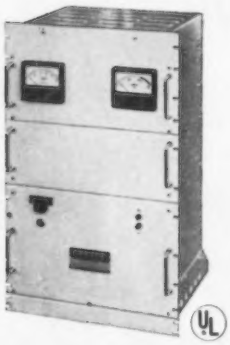
Kenneth R. Bragg
Parker Aircraft

W. Gifford Myers
Lockheed

Dr. Louis N. Ridenour
Lockheed

D-C POWER

Precisely Regulated for Missile Testing and General Use



CHRISTIE

SILICON POWER SUPPLIES

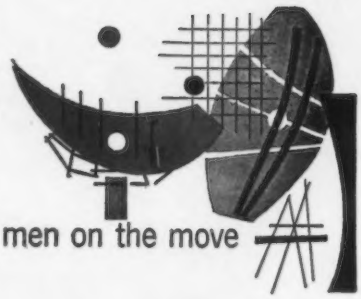
available in 30 standardized and militarized models from 30 to 1500 amps... 6 to 135 volts. CHRISTIE'S QUALITY CONTROL is approved by the A.E.C., leading aircraft and missile manufacturers.

Write For Bulletin AC-58-A

CHRISTIE ELECTRIC CORP.

3410 W. 67th Street
Los Angeles 43, Calif.

Circle 26 on Inquiry Card, page 83



men on the move

ARCH T. COLWELL, appointed vice president-engineering, research, and development, Thompson Ramo Wooldridge Inc.

DR. GEORGE C. SZEGO has joined the technical staff of Space Technology Laboratories, Inc.

WALTER W. MIEHER, appointed engineering manager of Sperry Gyroscope Company's Countermeasures Div.

JAMES WAGNER appointed coordinator of quality control for Garrett Corp. ROBERT EHINGER, named manager of personnel for the corporation's AiResearch Manufacturing Div.

ROBERT L. POTTER, promoted to manager of the manufacturing services department at Waste King Corporation's Technical Products Division. ARTHUR J. R. SCHNEIDER, promoted to chief engineer.

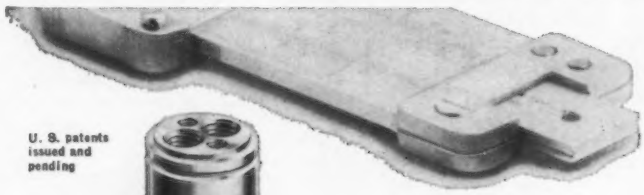
CHARLES NATER becomes chief engineer of the Instrument Div., Beckman & Whitley Inc.

Arch T. Colwell
Thompson Ramo Wooldridge

Dr. George C. Szego
Space Technology Laboratories

Robert L. Potter
Waste King Corp.

Charles Nater
Beckman & Whitley

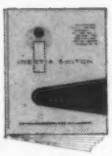


U. S. patents issued and pending

THIS is the actual size of the world's simplest acceleration switch.

It represents a totally new concept in acceleration-sensing devices. Weight: about one ounce. Only one moving part: a precision ground ball held by an alnico magnet. The ball is released to close or open an electric circuit when the force of acceleration exceeds the magnet's pull.

It's as simple as that. Yet this versatile I-S design makes possible switches that respond axially, radially, or omnidirectionally, from 0.01 g to 500 gs. With adjustable g settings, if you desire. Automatic reset is optional. Closure time is variable. Accurate within 0.1%. Meets all applicable Mil specs.



But more than an ingenious design, the I-S switch represents an important attitude . . . an attitude that produces only equipment of sound and simple design and reliable performance, of uses limited only by *your* needs. ***Try us; write today for descriptive brochure AMM-559.***

INERTIA SWITCH, INC. 311 W. 43d St., New York 36 • JUdson 6-5880

Circle 27 on Inquiry Card, page 83

KINGSLEY C. DRONE, appointed chief engineer of the Aircraft & Missile Div., Clearing Machine Corp.

HUGH H. GOODWIN, appointed sales representative, White Diesel Engine Div., The White Motor Co.

DR. VINCENT J. CUSHING, appointed a weapon system manager of the Missile & Space Systems Div., United Aircraft Corp.

WALLACE K. BOARDMAN, appointed sales manager of the new Aircraft Rocket Missile Engineering Div. (Armed) of Technical Oil Tool Corp.

GEORGE A. REED is president of the newly-formed Oxford Corp. JAMES A. MOTT is vice president. DEXTER ROSEN is secretary-treasurer.

DR. WILLIAM L. DAVIDSON, named technical coordinator of Food Machinery and Chemical Corp's activities in the rocket propellant field.

WALTER L. TANN has joined the staff of Aerojet-General Corp. as special assistant to the vice president and general manager.

JOHN H. TITLEY has been named sales manager for the Defense and Technical Products Div., Rheem Mfg. Co.

RALPH P. MORGAN, JR., appointed project manager for the development and testing of decoys in support of the intercontinental ballistic missile program at Aeronutronic Systems Inc.

Wallace K. Boardman
Technical Oil Tool Corp.

George A. Reed
Oxford Corp.

John H. Titley
Rheem Manufacturing Co.

Ralph P. Morgan Jr.
Aeronutronic Systems

AIRETOOL PNEUMATIC PRODUCTION TOOLS...

...small but mighty

Take Airetool pneumatic drills, for instance. Their high-torque air motors assure fast, clean drilling, yet these tools are compact, lightweight. Easily handled in close quarters. 3/32, 3/16, 1/4, 1/2, 5/8 and 3/4" models. Airetool angle head drills and midget grinders give this same efficient combination of size and power. Another good example is Airetool 500-V sander. Uses 7" flexible disc, weighs just 4 5/8 lbs. Write for Bulletin 67.

BRANCH OFFICES: New York, Chicago, Tulsa, Philadelphia, Houston, Baton Rouge
REPRESENTATIVES in principal cities of U.S.A., Canada, Mexico, South America, England, Europe, Puerto Rico, Italy, Japan, Hawaii
EUROPEAN PLANT: Vlaardingen, The Netherlands
CANADIAN PLANT: Brantford, Ontario

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD OHIO
30 years experience in pneumatic tools

Circle 28 on Inquiry Card, page 83

Interested in Learning Why

METROPOLITAN
MIAMI

HAS BECOME THE
INDUSTRIAL GIANT
OF FLORIDA?

HAS **2,400**
MANUFACTURING
CONCERNS
NOW IN OPERATION?

FOR THE FOURTH
CONSECUTIVE YEAR,
HAS GAINED ONE-THIRD
OF ALL NEW
MANUFACTURING JOBS
IN THE STATE?

Management Executives—

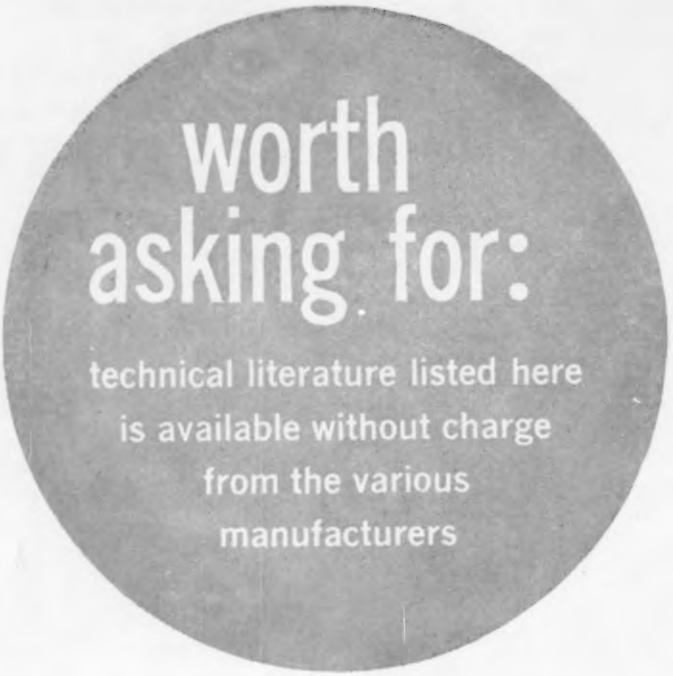
Send for new complete economic study of Metropolitan Miami

A 30 section, complete economic survey has just been prepared with complete data which will assist in determining how your particular operation can profit here. This important study will be mailed to you in strictest confidence — if you write, *on your letterhead*, to the address listed below. Sorry— we can't accept employment resumes. Seems like everyone wants to live in Miami.

Write:
John N. Gibson, Director
Dade County
Development Department
Section 76
Chamber of Commerce Building
345 N.E. Second Avenue • Miami, Florida

An agency of the Metropolitan Miami government

Circle 29 on Inquiry Card, page 83



Space Primer
Explanation of main physical laws in astronautics, with glossary, bibliography.
Convair Div., General Dynamics
Circle 121 on postcard for more data

R & D
23-pg booklet on MSVD.
Missile and Space Vehicle Dept. General Electric Co.
Circle 115 on postcard for more data

Electrode Catalog
Catalog is keyed to new A.W.S. specs, includes color code.
A. O. Smith Corp.
Circle 88 on postcard for more data

High Temperature Metals
50-pg. illustrated booklet includes definitions, techniques, selection, application, properties and processing data on high temperature metals.
Universal-Cyclops Steel Corp.
Circle 110 on postcard for more data

Steel Alloys
Design bulletin No. 8 describes advances in the state of the art of chemically milled steel alloys.
U. S. Chemical Milling Corp.
Circle 82 on postcard for more data

Systems Silencing
Complete manufacturing approach to aviation sound control described.
Koppers Co.
Circle 125 on postcard for more data

High Tensile Fastening
Design Manual offers high tentile fastener design considerations.
Elastic Stop Nut Corp. of America
Circle 100 on postcard for more data

Explosive Ordnance
Technical Data book on explosive ordnance products.
McCormick Selph Asso.
Circle 97 on postcard for more data

Modular Machines
Specification and engineering data catalog describes obsolescent-proof "Modular Machines" and components.
Cleveland Hobbing & Machine Co.
Circle 106 on postcard for more data

Packaged Environments
Four-page brochure describes "packaged" clean rooms.
Moore & Hanks Co.
Circle 96 on postcard for more data

Astronaut
First issue of new rocket industry quarterly.
Rocket Div.
Thiokol Chemical Corp.
Circle 86 on postcard for more data

Allison 250
Brochure on Allison 250 hp engine.
Allison Div.
General Motors Corp.
Circle 81 on postcard for more data

Hydraulic Servo Actuators
15-pg. booklet describes linear and rotary hydraulic servo actuators.
Dalmo Victor Co.
Circle 80 on postcard for more data

Tantalum Capacitors
Technical booklet.
Fansteel Metallurgical Corp.
Circle 126 on postcard for more data

Amplifiers
Eight-page color brochure entitled, "High Power Transistor Magnetic Servo Amplifiers."
Magnetic Amplifiers Inc.
Circle 83 on postcard for more data

Antennas
Revised, expanded antenna handbook.
I-T-E Circuit Breaker Co.
Circle 84 on postcard for more data

Fluorescent Markings
3-color bulletin illustrates daylight fluorescent aircraft markings.
Switzer Bros. Inc.
Circle 108 on postcard for more data

Drill Press
Bulletin on model 601 drill press with 2 inch stroke for small hole production drilling.
EPF Toll and Mfg. Co.
Circle 95 on postcard for more data

Tectrac
Bulletin on tension-truss concept for advanced radar tracking and scanning.
Narmco Mfg. Co.
Circle 127 on postcard for more data

Roll Planishing
Folder describes longitudinal and circumferential weld roll planishing machine.
Airline Welding and Engineering
Circle 118 on postcard for more data

Aircraft Components
Step-by-step look at equipment of component manufacturer.
Aviation Divs.
Kelsey-Hayes Co.
Circle 92 on postcard for more data

Spring Steel
43-page spring steel stock list booklet form.
Uddeholm Co. of America
Circle 123 on postcard for more data

Ultrasonics
Ultrasoundings, firm's quarterly on ultrasonics.
Acoustics Assoc. Inc.
Circle 131 on postcard for more data

Weight Handbook
Handbook lists weights of firm's standard AN-NAS-MS hydraulic fittings.
Arnav Aircraft Assoc. Inc.
Circle 104 on postcard for more data

Pipe Plugs

Bulletin describes line of pipe plugs.

Lock Thread Corp.

Circle 113 on postcard for more data

Spindle Machines

Bulletin on firm's spindle machines for finished parts.

Almco-Queen Prods. Div. King-Seeley Corp.

Circle 107 on postcard for more data

Stock Gears

Handbook on fine pitch precision stock gears.

U. S. Gear Corp.

Circle 102 on postcard for more data

Vacuum Arc Furnace

Vacuum arc furnace used to produce shaped castings and ingots of titanium, zirconium and other hard-to-melt metals is subject of a new data sheet.

NRC Equipment Corp.

Circle 101 on postcard for more data

Ballistic Reel

Bulletin on ballistic harness inertia reel.

Talco Engineering Co.

Circle 116 on postcard for more data

Time Delay Relays

Specifications of miniature agastat time delay relays.

Elastic Stop Nut Corp. of America

Circle 117 on postcard for more data

Servomanometers

Illustrated 16-pg. bulletin 500 on servomanometers, technique and types.

Exactel Inst. Co.

Circle 119 on postcard for more data

Pneumatic-Vacuum Catalog

Hydraulic pneumatic and vacuum-catalog contains helpful information for engineering and maintenance departments.

Lenz Co.

Circle 89 on postcard for more data

Thermocouples

4-page bulletin describes magnesium-oxide-insulated, metal-sheathed heat-and-shock-resistant thermocouples and conductors for high temperature and atomic application.

Tuttle & Kift Div. Ferro Corp.

Circle 129 on postcard for more data

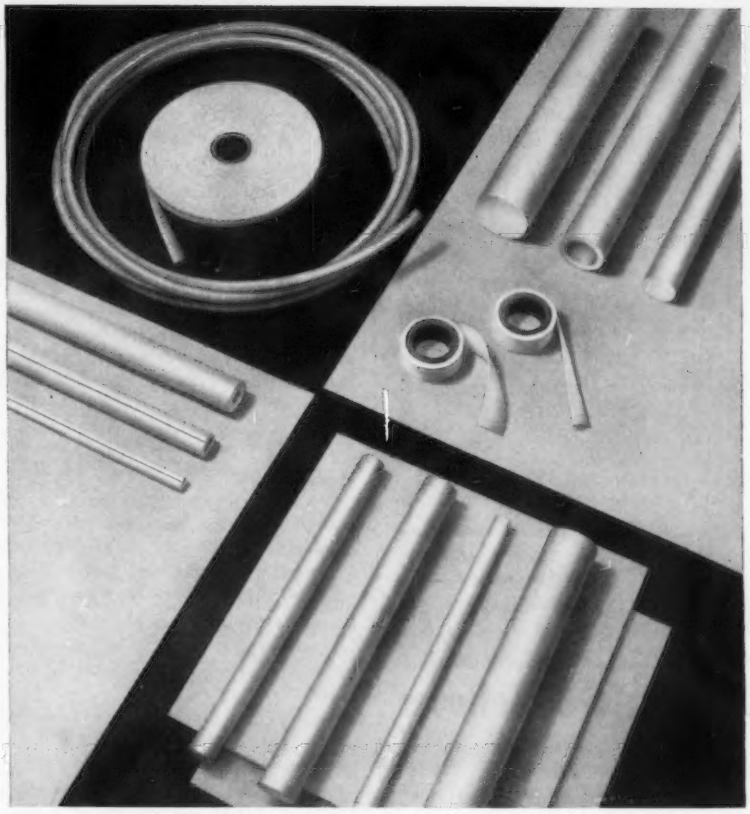
Catalog

Loose-leaf catalog covers complete line of spectrographic and analytical chemical equipment and laboratory services.

National Spectrographic Labs.

Circle 91 on postcard for more data

LOOK TO R/M TO MEET ALL YOUR TEFLON* NEEDS



R/M—headquarters for "Teflon" products. R/M can meet all your needs for sheets, rods, tubes, tape, thin-wall tubing (available with permanent color striping for identification purposes) and bondable "Teflon." R/M can also supply molded, machined and extruded "Teflon" made to your exact specifications.

"Teflon's" many remarkable properties have established it as an important material for use in aircraft, missiles and spacecraft. Yet when you select "Teflon" for a particular job, you solve only part of your problem. Equally important is the selection of a source of supply you can depend on for both competent engineering assistance and the production capability needed to meet your exact specifications and quantity requirements. This *complete* "Teflon" service is yours from R/M.

A pioneer in "Teflon" application and fabrication research, R/M offers design guidance that can help assure maximum part performance, and its ample production facilities can supply "Teflon" in the form best suited to your needs. Learn more about R/M's complete "Teflon" service—and how it can benefit you—by contacting your nearest R/M district office. Or write Plastic Products Division, Manheim, Pa.

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R/M

RAYBESTOS-MANHATTAN, INC.

PLASTIC PRODUCTS DIVISION FACTORIES: MANHEIM, PA.; PARAMOUNT, CALIF.

Contact your nearest R/M district office listed below for more information or write to Plastic Products Division, Raybestos-Manhattan, Inc., Manheim, Pa.

BIRMINGHAM 1 • CHICAGO 31 • CLEVELAND 16 • DALLAS 26 • DENVER 16 • DETROIT 2 • HOUSTON 1
LOS ANGELES 58 • MINNEAPOLIS 16 • NEW ORLEANS 17 • PASSAIC • PHILADELPHIA 3
PITTSBURGH 22 • SAN FRANCISCO 5 • SEATTLE 4 • PETERBOROUGH, ONTARIO, CANADA

RAYBESTOS-MANHATTAN, INC., Engineered Plastics • Asbestos Textiles • Mechanical Packings • Industrial Rubber Sintered Metal Products • Rubber Covered Equipment • Abrasive and Diamond Wheels • Brake Linings Brake Blocks • Clutch Facings • Laundry Pads and Covers • Industrial Adhesives • Bowling Balls

flatness of 1/2 to 1 light band (0.000006 to 0.0000116)

•

finish of 2 to 4 micro inch

DIAMOND IMPREGNATED

LAPPING PLATES

FOR TOUGH FINISHING JOBS ARE OUR SPECIALTY

Crowe Tool Co.

5th and Chestnut sts.
Riverside, N. J.

PHONE HO 1-0362

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STAINLESS

FlexDucts & Bellows

- which handle high temperature corrosives
- which withstand drastic pressure changes, vibration & sinuous alignment

. . . designed and fabricated by U. S. Flex

Write for technical data

U.S.Flex

U. S. FLEXIBLE TUBING CO.
213 MAIN STREET BARTLETT, ILLINOIS

Circle 32 on Inquiry Card, page 83

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Facilities

Firm's rolled tooling plate used to make industrial tools, jigs and fixtures.

Kaiser Aluminum & Chemical Sales
Circle 98 on postcard for more data

Air Control Valves

"Valve Finder" features a discussion of air valves and their selection together with condensed catalog listings.

Hannifin Co.
Circle 132 on postcard for more data

Products Catalog

63-pg. illustrated catalog on all of firm's finished steel and wire products.

Colorado Fuel & Iron Corp.
Circle 90 on postcard for more data

Electrical Ground Power

Copy of talk on electrical ground power for commercial jet aircraft.

Motor Generator Corp.
Circle 103 on postcard for more data

Facilities

Brochure shows facilities from design to completion.

St. Louis Car Co.
Circle 99 on postcard for more data

Measurements

Bulletin describes PG-800 Hole Gate and its PG-400 Setting Fixture for precision measurements of hole diameters.

Sunnen Service Corp.
Circle 109 on postcard for more data

RA330

Bulletin No. 107 is a six page combination file folder on RA330 heat-resisting alloy.

Rolled Alloys, Inc.
Circle 114 on postcard for more data

Silicones

Brochure covers use of silicones to aid miniaturization, weight reduction and reliability.

Dow Corning Corp.
Circle 120 on postcard for more data

Cannon Plugs

Aluminum RF cannon coaxial connectors described.

Cannon Electric Co.
Circle 112 on postcard for more data

Steel Sheets and Strip

Revised bulletin lists types of sheet and strip available.

Joseph T. Ryerson & Son
Circle 122 on postcard for more data

Laminated Plastic

Data Bulletin 4.5.1 describes Grade G-5 high strength, flame resistant laminated plastic.

Taylor Fibre Co.
Circle 111 on postcard for more data

Data Sheet

Sheet describes Speedomax G multiple-point recorder controller assembly.

Leeds & Northrup Co.
Circle 93 on postcard for more data

Rotary Surface Grinder

8-page bulletin describes model 161 rotary surface grinding machine for precision grinding.

Heald Machine Co.
Circle 124 on postcard for more data

Laboratories

Network of screw-thread-measuring laboratories described.

Standard Pressed Steel Co.
Circle 105 on postcard for more data

Warehousing

Brochure describes fully-automatic warehouse system.

Pesco Products Div.
Borg-Warner Corp.
Circle 133 on postcard for more data

Thermometers

Eight-page booklet describes line of stainless steel thermometers.

W. C. Dillon & Co.
Circle 130 on postcard for more data

Electro-mechanical Assembly

16-page catalog provides features and specifications on line of electro-mechanical assembly components.

Servo Corp. of America
Circle 85 on postcard for more data

Flexible Ball Joints

Four-page catalog on Flexible Ball Joints (also known as Swing or Swivel Joints) for handling liquid oxygen and high energy fuels.

Barco Manufacturing Co.
Circle 87 on postcard for more data

Dies

Bulletin AFD-958 describes Chicago Alloy-Form dies for press brakes.

Dries & Krump Manufacturing Co.
Circle 94 on postcard for more data

Test Equipment

Types of test equipment pictured.

George L. Nankervis Co.
Circle 128 on postcard for more data

industry notes

VANGUARD'S VERTICAL LIFT

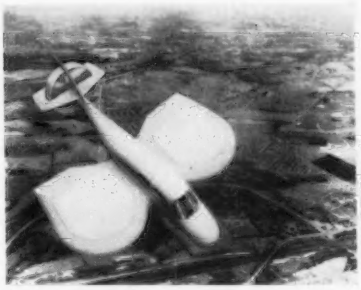
Close to rollout — prototype of fan-in-wing vertical lift aircraft with rotors buried in each wing. It's the first test aircraft of Vanguard Air and Marine Corp., formed Feb., 1958, by two aircraft executives formerly with Piasecki Aircraft.

The basically-fixed-wing plane is designed to change from hovering to forward flight by means of closures for each wing rotor. Tail assembly also contains a shrouded propeller. This provides pitch and yaw control in hovering as well as forward propulsion.

Two-place prototype, primarily aluminum, is 24 ft long with 22 ft wingspread. Takeoff can be either vertical, STOL, or conventional. Top planned speed on prototype: 190 mph.

The aircraft was designed by Edward G. Vanderlip, Vanguard president, and John J. Schneider, vice president, engineering. The former had been Vice President and Director of Special Projects at Piasecki. Staff of the firm, now headquartered near Paoli, Pa., totals 19.

Prototype was entirely privately financed. Firm hopes



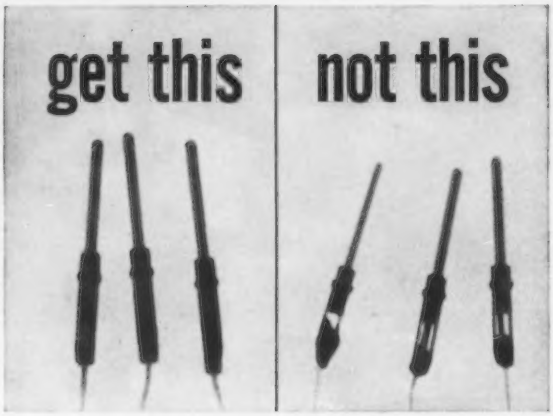
that future manufacture and testing will be under auspices of a government agency. Initial manufacturing cost was kept low by using dynamic parts from the Jacobs convertiplane of 1954, an unloaded rotor type of aircraft. Fan-in-wing concept itself dates back to the early 1900's.

MERCURY CAPSULE

Beryllium heat shield will protect occupant of Project Mercury space capsule from reentry heats. Shallow cone (84 in. diam.) will be fabricated by "hot upsetting" at Brush Beryllium in Cleveland.

½ ACRE OF HONEYCOMB USED IN NAA'S B-70

Some 20,000 sq ft of honeycomb will go into skin of North American's B-70. Type: PH 15-7 MO CRESS with stainless expanded core.



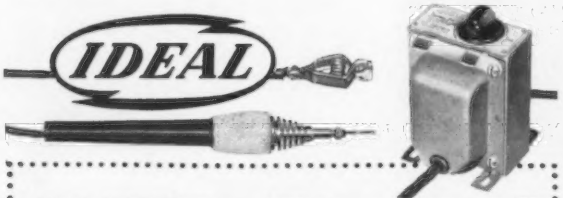
Actual X-ray Photos Show How IDEAL Thermo-Tip Resistance Soldering Tools Reduce Costly Voids in Winchester and Cannon Plug Pins

Because the whole pin is heated, "cold-flow joints" are eliminated; failures are greatly reduced

	Conduction Method		Resistance Method	
Pin No.	Length of void	% of void	Length of void	% of void
1	0.12"	40	0.00"	0
2	0.12"	40	0.00"	0
3	0.07"	23	0.05"	17
4	0.18"	60	0.00"	0
5	0.06"	20	0.06"	20
6	0.05"	17	0.04"	13
7	0.02"	7	0.05"	17
8	0.08"	27	0.01"	3
9	0.09"	30	0.07"	23
10	0.12"	40	0.09"	30
11	0.15"	50	0.04"	13
12	0.12"	40	0.06"	20
13	0.09"	30	0.01"	3
14	0.12"	40	0.08"	27
15	0.11"	37	0.02"	7
16	0.10"	33	0.04"	13
17	0.07"	23	0.04"	13
18	0.09"	30	0.09"	30
19	0.11"	37	0.10"	33
20	0.11"	37	0.06"	20
21	0.05"	17	0.01"	3
22	0.15"	50	0.00"	0
23	0.11"	37	0.05"	17
24			0.07"	23

● These production test results from a major Aircraft manufacturer prove the superiority of Ideal Resistance Soldering Tools to the best available commercial soldering irons. Voids averaged 33% with soldering irons. With resistance soldering only 14%.

In addition, higher production speeds were possible on Cannon plugs and operators were less subject to painful burns. Send for descriptive literature.



IDEAL INDUSTRIES, Inc., 1390E Park Ave., Sycamore, Ill. (IDEAL)
Gentlemen: Please send complete catalog information about Ideal's Thermo-Tip Resistance Soldering Tools.

Name_____
Company_____
Address_____
City_____ Zone____ State_____

CONTRACTS

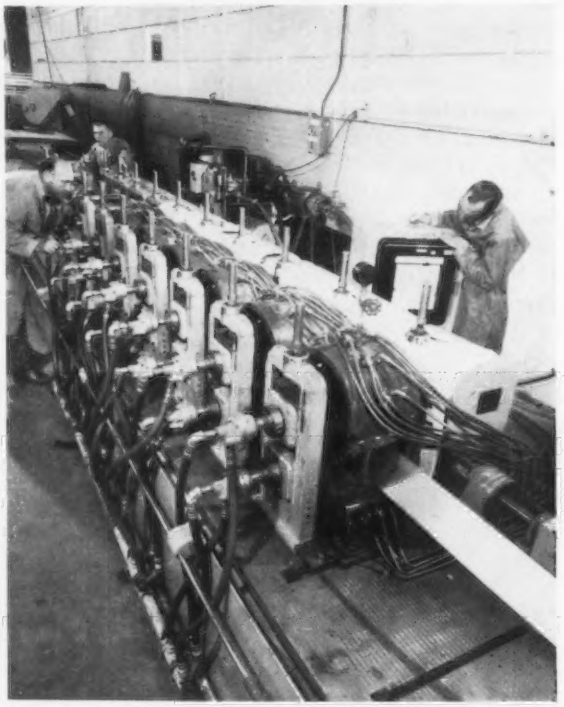
Recent contracts in aircraft and missile manufacturing and allied fields:

The Navy awarded a $101,701,000 cost-plus-incentive-fee contract to Grumman Aircraft for development and production of a new carrier-based jet, the A2F-1. Grumman has also received a $93-million contract for the new W2F-1 prop-jet early-warning plane. Included in W2F-1 award: $24-million pre-production contract enabling Grumman to start work before complete pact was signed.

A $61.8 million Navy contract went to McDonnell Aircraft for initial production of F4H-1 all-weather airplanes. McDonnell's initial contract for Project Mercury space capsule was announced: $10,500,000.

The Air Force selected Convair, Fort Worth, to work (along with General Electric's Nuclear Propulsion Div.) an initial design of a nuclear powered bomber prototype.

FORMING TITANIUM



Titanium high-strength alloy is formed successfully on a Yoder Roll at Boeing Airplane Co. Often, titanium can be formed only in the 1,000-1,600° F range. Modified Yoder Roll includes enclosed heating to reach forming temperature. Furnaces, each with 18 burners around its periphery, enclose each set of rolls. Water runs through hollow shafts to cool bearings. Rolling speed of 1½ ft per minute has been attained. Boeing hopes to reach 12 to 15 times this rate.

Other aircraft contracts went to Solar Aircraft, engine extraction air ducting system for B-70 bomber; Sperry Gyroscope, for twin-gyro platform for B-70 attitude and reference data; Bell Helicopter Corp., Fort Worth, $20,817,626 for HU-1A helicopters and related equipment; General Electric, $8,300,000 for further development of the J93 jet engine.

Minneapolis Honeywell Regulator Co. got $8-million for automatic pilots for the Air Force's F-101B Voodoo; and Kaman Aircraft, $14-million, from Navy for HU2K-1 helicopters. The Air Force cancelled production of Republic's F-105E two-place jet in favor of F-105D single seaters.

In missiles, the Air Force awarded Aerojet-General Corp. an $85-million contract for research and development of all three stages of the Minuteman at the Sacramento plant. The Navy announced a $64.6-million follow-on production contract with Raytheon Mfg. Co. for Sparrow III guided missiles. Air Force contracts with Boeing Airplane Co. for IM-99B Super Bomarcs were announced: $300-million. Boeing has been alloted $152-million for Minuteman R & D over four years. Fiscal 1960 allotment: $55-million. NASA signed a $5-million contract with General Electric for liquid propellant engine for Vega second stage (engine is modification of Vanguard first stage engine).

In other missile contracts, Martin's Baltimore Div. received $2,400,000 from Air Force for expanding its Mace program, and $2,078,000 from Army for Pershing R & D. Philco received $13,500,000 from Navy for Sidewinders; Western Electric, $6,372,500 for R & D on Nike Zeus; American Machine & Foundry Co., $12,-125,000 from Air Force for Titan base launchers; and General Electric MSVD, $500,000 for R & D on Little John.

General purpose missile is carried by Straddle Carrier of Short Brothers & Harland Ltd., which recently acquired the British Straddle Carrier Co. Carrier carries missile by itself or together with its own wheeled trolley.

TECHNICAL PROSPECT

Code 9019 Multiform glass developed by Corning Glass Works may be hermetically fused to 430 Ti and 446 stainless steel in a low-compression-type seal.

Neodymium, hitherto only commercially available as an oxide or salt, is now being produced in pure form by Nuclear Corp. of America. Inquiries: Research Chemicals Div., Burbank, Calif.

MST 881, high temperature titanium alloy of Mallory-Sharon Metals Corp., is being tested for use in compressor shafts, wheels and blades of Mach 3 jet engines.

Fabric impregnated with phenolic plastic may prove useful in aircraft uni-ball joints and trim-tab bearings. Manufacturer: Russell Mfg. Co., Middletown, Conn.

Beta embrittlement in some high strength titanium alloys is caused by large beta-grain size attained during heat treatment, according to Report PB 151278, Office of Technical Services.

High-heat-resistant plastic, designated PL-11, has been developed for injection molding and extrusion by J. T. Baker Chemical Co., Phillipsburg, N. J.

Republic Aviation has developed corrugated sandwich metal paneling for jet airplanes and spacecraft. Paneling withstands 2,000°F.

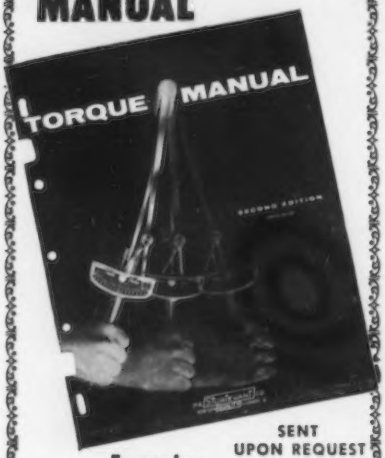
Mass spectrometer technique has been applied to lubricating oil by Gulf Oil Corp. Knowledge of molecular composition may allow tailoring specific oils to different jobs by molecular composition.

New flexible hose of DuPont "Viton" synthetic rubber was developed by Thermoid Div., H. K. Porter Co. Hose can be used with jet fuels over a wide range of temperatures, may be good of handling liquid missile fuels.

Highly-fluorinated high temperature synthetic elastomer developed by the Chemical Div., Minnesota Mining and Manufacturing Co., may have broad

continued on next page

"TORQUE WRENCH" MANUAL



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Formulas
Applications
Engineering Data
Screw Torque Data
Adapter Problems
General Principles

P.A. STURTEVANT CO.
ADDISON QUALITY ILLINOIS

Circle 35 on Inquiry Card, page 83

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Circle 36 on Inquiry Card, page 83

industry notes

applications in the fuel and hydraulic systems of missiles and aircraft.

New formulation for Etchalume 14, etching and cleaning compound for aluminum, doubles effectiveness, according to Enthone, Inc., New Haven, Conn. manufacturer.

New Office of Technical Services catalogs list reports on uranium, its alloys and compounds.

Entek 45, liquid additive to hot water rinses, prevents water spotting and subsequent corrosion of metals. Developer: Enthone Inc., New Haven, Conn.

Teflon-impregnated glass cloth of Continental Diamond Fibre Corp. is being used in new laminated plastic for corrosive applications in gaskets and seals.

Flame - resistant laminated plastic developed by National Vulvanized Fibre Co., is being recommended for printed circuit applications.

New B. F. Goodrich adhesive, A-978-B, allows sheet steel to be bonded to vinyl plastic, embossed and then deep-drawn without ruining adhesion.

High temperature graphite has low friction and wear rates at 1200°F. Manufacturer: Stackpole Carbon Co., St. Marys, Pa.

New Titanium ingot melting process has been developed by Johnston & Funk Metallurgical Corp., Wooster, O. It removes major contaminants of oxygen and nitrogen in vacuum melted titanium ingots below 1/10 of 1 per cent.

ENGINEERS & SCIENTISTS

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Cincinnati, Ohio

Teams of engineers and scientists in our division are working on far advanced jet and rocket engines and new approaches to space propulsion.

IMMEDIATE NEEDS FOR:

VIBRATION/MECHANICAL ANALYSIS: AE or ME with 2 years experience in applied mechanics, to establish experimental programs for development engines.

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COMBUSTION ENGINEER: ME with 2 years development experience for J93 Project (powering the B-70).

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MECHANICAL DESIGN RELIABILITY: ME or AE with 3 years gas turbine experience, to review designs for reliability and carry out reliability program for development engines.

SCIENTISTS: MS or PhD and related experience for major programs in plasma jet, ion propulsion, other advanced concept programs.

MAIL YOUR RESUME OR THIS COUPON TO THE ADDRESS BELOW:

Mr. Mark Peters
Bldg. 100, Dept. 80-ME
Flight Propulsion Division
General Electric Company
Cincinnati 15, Ohio

I want to learn more about FPD research and engineering. Please send "Thrust & Progress" brochure.

NAME .....
ADDRESS .....
.....
.....DEGREE ..... YEAR.....

Circle 37 on Inquiry Card, page 83

FACILITIES

Lockheed Aircraft Corp. bought controlling interest in Puget Sound Bridge & Dredging Co. of Seattle. Lockheed plans expansion, looks for increased business building atomic submarines, ground support facilities for missiles and space vehicles. Lockheed has also set up a separate electronics division called the Lockheed Electronics and Avionics Div.

Hexcel Products Inc. has acquired from Honeycomb Div., Young Spring and Wire Co., all the latter's production equipment for manufacture of corrugated aluminum honeycomb.

Rolls-Royce Ltd. and Westinghouse Electric Corp. announced continued collaboration in the aircraft engine field. They plan joint development of a military propeller turbine.

Ryan Aeronautical Co. is installing a complete high energy forming facility in its San Diego plant. Using a die, explosive, and water-filled pit, facility moves metal parts into shape at speeds of 200 to 500 ft per sec.

Servomechanisms Inc. will build a new 48,000 sq. ft. plant adjacent to its present facility at Hawthorne, Calif.

Aerotech Specialties Inc. has changed its name to United Sensor & Control Corp.

Kearfott Co. has expanded its Engineering Div. into a leased 33,000 sq. ft. plant in Clifton, N. J. Expansion is for work on guidance and control systems for aircraft, missiles, and space navigation problems.

The Beryllium Corp. is expanding its fabrication facility at Hazleton, Pa., to supply rising demand in beryllium parts for the aircraft and components market.

North American Aviation announced agreement to acquire Foster Wheeler Corp., which is active in nuclear power field, for about $27,763,000.

Halco Plastics has moved to larger facilities at 11200 Wright Rd., Lynwood, Calif.

The Albuquerque, N. M. organization of ACF Industries Inc. has become a separate div. of the firm in order to shorten firm's lines of communication with the AEC.

Temco Aircraft Corp. now has a corporate development planning organization.

Propulsion Test Facilities Inc., newly-formed affiliate of MB Mfg. Co., is offering "packaged" environmental test facilities for customers in the aircraft and missile industries. Included are engineering, design, production, and construction capabilities.

Hooker Chemical Corp. has formed a Western Chemical Div.

Missile wing assembly output is being increased at Iron Fireman Mfg. Co.'s Aircraft Parts Div., Portland, Ore. Firm has installed over $100,000 worth of new steel and aluminum sculpture milling equipment.

Agreement between Aerojet-General Corp. of Azusa and Mitsui & Co., Ltd., Tokyo, makes latter exclusive sales representative in Japan for Aerojet's JATO and Aerobee rockets. It marks Aerojet's expansion into Far Eastern field.

Flodar Corp., Cleveland, and Thompson Ramo-Wooldridge have concluded an arrangement whereby latter will manufacture and market improved line of aircraft tube fittings to the advanced aircraft and missile fields.

Atomic Personnel Inc., Phila., has been formed as placement service devoted exclusively to the nuclear field.

Corning Glass Works has transferred production and sale of its fused silica delay lines to its Electronic Components Dept., Bradford, Pa. Fused silica enables Corning to make ultrasonic delay lines storing a signal from less than 50 to over 15,000 microseconds.

Hardman Tool & Engineering Co., Los Angeles, is now a wholly-owned subsidiary of Dayton Rubber Co.

New facility now operating at Chance Vought Aircraft uses 10 inch ram jet engine to generate 3500° heat for testing nose cones.

First section of Linde Company's multi-million-dollar oxygen-nitrogen producing plant is expected to begin operating at Pittsburg, Calif. this month. Target output: 300 tons of liquid oxygen and nitrogen per day.

USE THIS NEW KIND OF DIAMOND CUT-OFF WHEEL

Gives narrower, smoother cuts on industry's toughest materials

...yet prices start at only $32.25

Now...at *production prices*... DIATRONIC gives you a rim width of .006" that's accurate to a maximum total tolerance of .0005"—or your money back. This accuracy is built in by a new process. No break-in needed. New narrow cut reduces sawdust loss 30%. A must for $3,000-a-pound silicon or germanium crystal. Cuts tungsten carbide, corundum, aluminum oxide, glass...practically anything. Stock orders shipped in hours; special wheels available. Write for literature, price list.

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NAVAN PRODUCTS, INC.
Subsidiary of North American Aviation, Inc.
Dept. 282, International Airport, Los Angeles 45, Cal.

DIATRONIC* DIAMOND WHEELS
"with built-in tolerance" *TRADEMARK

Aircraft and Missiles Manufacturing is read by the key design, engineering, production and procurement men in plants producing aircraft, missiles, power plants, and parts.

CAE
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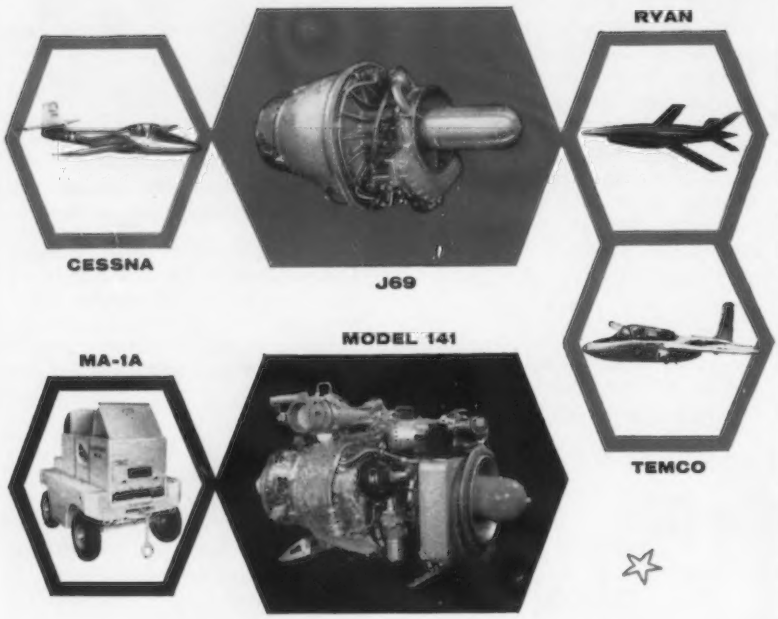
Building Tomorrow's Power



Continental Aviation & Engineering Corporation has more than 10 years' experience with small gas turbine engines.... Four versions of the J69 turbojet—delivering 920 to 1700 lbs. thrust—are in operation today. . . . The Model 141 turbine air compressor engine is widely used in jet aircraft ground support equipment. . . . Research and development programs are continuously in process on uprated turbines, new turbine configurations, solid fuel propellents, and solid fuel ramjet vehicles.

CONTINENTAL AVIATION & ENGINEERING CORPORATION
12700 KERCHEVAL AVENUE, DETROIT 15, MICHIGAN
SUBSIDIARY OF CONTINENTAL MOTORS CORPORATION

industry notes

TERRA-SCOPE

Republic Aviation's cost-cutting program saved $6-million last year. Over $900,000 of this resulted from a "value analysis" procedure in the Procurement Dept. Slowing down drill motors in production shops for increased drill-life saved $35.-000.

•

Stronger weld joints may result from ultrasonic vibrations of metal at the site of the weld during the welding process, according to report from Battelle Memorial Institute.

•

Adoption of the new international inch on July 1 will have big impact on manufacturers of gage blocks, precision components, close tolerance machines. New figure (25.4 mm) is 2 millionths less than the present inch, and 1.7 millionths greater than the British Imperial inch.

•

The Air Force plans to cut number of wings to 90 by mid-1964. Plans call for interceptors to be armed with the atomic-tipped Genie rocket by that time. Strategic B-52G bombers will carry the nuclear Hound Dog.

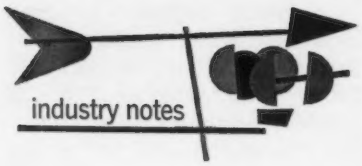
•

The booster for the secret design Nike-Zeus missile has been test fired at the Army Rocket and Guided Missile Agency. Sources said it developed several hundred thousand pounds thrust.

•

Deliveries of 130 Alouette II helicopters from Sud Aviation to the German Federal Republic begins this month.

continued on page 80



INDUSTRY STATISTICS

Source: Bureau of the Census and Civil Aeronautics Administration.

NUMBER AND VALUE OF CIVIL AIRCRAFT SHIPMENTS

Month	Units		Value in Thousands	
	1959	1958	1959	1958
January	665	582	$ 49,590	$ 63,249
February	619	518	49,805	67,515
March	.....	708	.....	38,417
April	.....	708	.....	48,677
May	.....	630	.....	37,616
June	.....	592	.....	26,421
July	.....	503	.....	41,587
August	.....	471	.....	30,776
September	.....	399	.....	24,401
October	.....	628	.....	49,328
November	.....	531	.....	34,881
December	.....	612	.....	37,672
Total—Year	.....	6,882	.....	$500,540
Total—2 Mos.	1,284	1,100	$ 99,395	$130,764

AIRFRAME WEIGHTS OF CIVIL AIRCRAFT SHIPMENTS

Month	Thousands of lbs.		Avg./Aircraft	
	1959	1958	1959	1958
January	1,452.8	1,932.0	2,185	3,320
February	1,440.0	1,951.7	2,326	3,768
March	.....	1,397.0	.....	1,973
April	.....	1,635.8	.....	2,310
May	.....	1,356.6	.....	2,153
June	.....	1,093.1	.....	1,846
July	.....	1,418.7	.....	2,820
August	.....	1,106.0	.....	2,348
September	.....	855.2	.....	2,143
October	.....	1,545.6	.....	2,461
November	.....	1,107.1	.....	2,085
December	.....	1,258.9	.....	2,057
Total—Year	.....	16,657.7	.....	2,420
Total—2 Mos.	2,892.8	3,883.7	2,253	3,531

SHIPMENTS OF PISTON ENGINES FOR CIVILIAN AIRCRAFT

Month	Units		Value	
	1959	1958	1959	1958
January	873	1,033	$ 2,635,000	$ 8,883,000
February	954	1,139	2,729,000	9,696,000
March	.....	994	.....	8,174,000
April	.....	881	.....	8,174,000
May	.....	828	.....	6,176,000
June	.....	783	.....	5,994,000
July	.....	730	.....	4,898,000
August	.....	693	.....	3,420,000
September	.....	757	.....	3,312,000
October	.....	811	.....	3,336,000
November	.....	786	.....	2,815,000
December	.....	798	.....	2,965,000
Total—Year	.....	10,233	.....	$ 67,843,000
Total—2 Mos.	1,827	2,172	$ 5,364,000	$ 18,579,000

TOTAL HP. OF AIRCRAFT PISTON ENGINE SHIPMENTS FOR CIVILIAN USE

Month	Total Hp. (in Thousands)		Avg. Hp. per Engine	
	1959	1958	1959	1958
January	196.2	468.9	225	454
February	206.7	518.2	217	455
March	.....	440.7	.....	443
April	.....	428.0	.....	486
May	.....	338.3	.....	409
June	.....	328.7	.....	420
July	.....	282.1	.....	386
August	.....	210.0	.....	303
September	.....	214.0	.....	283
October	.....	220.9	.....	272
November	.....	198.6	.....	253
December	.....	201.7	.....	253
Total—Year	.....	3,850.1	.....	376
Total—2 Mos.	402.9	987.1	221	454

VALUE OF SHIPMENTS OF AIRCRAFT PROPELLERS AND PARTS

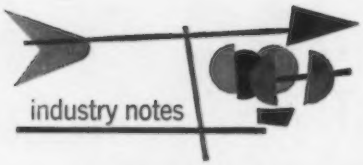
All data are in Thousands of Dollars

Period	Total All Products	For Military Aircraft	For Civilian Aircraft	Other Products†
1958				
First Quarter	$ 65,500	$38,983	$ 9,503	$17,014
Second Quarter	68,101	36,564	9,296	22,241
Third Quarter	51,185	27,479	6,445	17,261
Fourth Quarter	45,334	18,727	8,128	18,479
Total—1958	$230,120	$121,753	$33,372	$74,995
1957				
First Quarter	$ 51,079	$20,767	$11,599	$18,713
Second Quarter	60,772	27,065	11,483	22,224
Third Quarter	66,194	31,658	7,836	26,700
Fourth Quarter	72,140	41,117	10,800	20,223
Total—1957	$250,185	$120,607	$41,718	$87,860

†—Includes experimental work.

SHIPMENTS OF PROPELLERS FOR CIVILIAN AIRCRAFT

	1958	1957
January	1,132	1,148
February	1,186	1,403
March	1,202	1,629
April	1,358	1,475
May	1,299	1,572
June	1,307	1,419
July	1,130	1,120
August	1,153	1,192
September	1,089	1,152
October	1,098	1,338
November	1,102	1,372
December	1,058	1,194
Total	14,114	16,014



Martin is working towards nuclear auxiliary power far more advanced than "SNAP III," which one official likens to "a kiddycar before a cadillac." AEC's plasma thermocouple—converting fission heat into electricity without steam — is believed a considerable advance over SNAP III.

•

Omega Aircraft's BS-12 twin engine utility helicopter is expected to be certified by the FAA this month. 25 are planned for production this year.

•

General Electric's Flight Propulsion Div. has signed formal agreements with the Federal Republic of Germany for the latter's licensing of J79 jet engines.

The Rolls-Royce Dart R. Da. 10 turbo-prop has successfully completed a 150 hr test on a combined U.S./U.K. civil type test schdule at dry takeoff rating of 2,660 t.e. h.p. (2,400 shaft h.p. plus 670 lb thrust). Boosted with water-methanol, Dart also completed 25 hr flight approval test at 3,200 shaft h.p.

•

Riddle Airlines is route-proving Hawker Siddeley's Argosy turboprop freighter. Riddle says use of the jet-powered freighters should save 20 per cent in handling expenses.

•

Tough stainless steel skin sections for Atlas will be formed by new Cyril Bath 50 ton radial draw former. The $500,000 machine, most expensive single piece of equipment at Convair's Astronautical Lab, will radial form a 48-inch sheet. It can stretch from two to 50 tons. Hydraulically-driven, it is 92 ft long, weighs 100 tons.

First turbine - powered hydrofoil water craft, manufactured by Miami Shipbuilding Corp., uses Lycoming T53 gas turbine, combined with hydrofoil "wings." Latter lift entire craft from water except for hydrofoils themselves, and speeds exceed 30 knots.

•

The Army is developing Pershing on an accelerated basis which marks a relatively new approach to a weapon system. Instead of usual sequential pattern—from developer, to Army for testing, then back to prime for modifications—Army users are consulted at design completion.

•

On the drawing boards at Rocketdyne for future development—rocket engine delivering 20 million pound thrust. It would consist of a cluster of four five-million-pound-thrust engines. Rocketdyne says it would be ready within 25 years.

The TITAN "Target" STUD DRIVER

Engineered for the Aircraft and Precision Engine Industry

The TITAN "Target" Hex Collet Stud Driver drives the stud by pitch diameter pressure instead of pressure on the top of the stud. This method completely eliminates mutilation and stretching of stud threads, and distortion of cotter key holes.

The famous TITAN BALL BEARING COLLET RELEASING MECHANISM (exclusively Titan) effects release of the collet with a fraction of the torque necessary with other methods. Reversing the motive power causes the driving head to move upward as well as backward, thus releasing pressure on the collet and freeing the stud.

Can be adjusted for various lengths of grip on the stud simply by lifting the clutch ring and screwing the collet holder farther onto the sleeve for a shorter grip or farther off the sleeve for a longer grip.

Furnished with either a ½" female square for mounting on air drills or with ⅝"—16 female thread in top of driver. Morse Taper Shanks and Hex Shanks are available; also T-Handles for hand use.

Write for details, TODAY!

TITAN TOOLS — World's Largest Producers Of Stud Drivers And Pullers

TITAN TOOL CO.

48 MAIN ST., FAIRVIEW (ERIE COUNTY), PA.

Circle 40 on Inquiry Card, page 83

(Advertisement)

To Maintain RELIABILITY In Transit Pre-Test with IMPACT-O-GRAPH

Manufacturers of delicate instruments for Aircraft and Missiles have learned that Quality Control is not enough to assure delivery of their products in undamaged condition.

Receivers of instruments now demand RELIABILITY. This simply means the assurance that the product is in proper working condition when it arrives at its destination.

The IMPACT-O-GRAPH is used to measure the shocks and impacts to which a product has been subjected. Test shipments are also made to pre-determine what kind of treatment is to be expected. With such data, the package engineer can design the proper package to protect the product under known shipping conditions.

The IMPACT-O-GRAPH further determines what degree of shocks or forces render the product unusable. This is particularly important in transporting delicate instruments.

IMPACT-O-GRAPH is an entirely self-contained three-way recorder. Shocks are graphed on a coated tape. It is available in many different sensitivities. Some models record the impact in connection with the time element involved. Others are impact activated; that is, the tape advances when the recorder is subjected to impact.

Many government agencies insist that the IMPACT-O-GRAPH be used by their suppliers for shipping delicate instruments.

Write now for the brochure telling the whole story. IMPACT-O-GRAPH is National Safe Transit approved.

THE IMPACT-O-GRAPH CORPORATION

1900 Euclid Ave., Cleveland 15, Ohio

Cherry 1-5838

Circle 41 on Inquiry Card, page 83

Inflatable sphere part of the ill-fated Vanguard of April 14 would have been most economical satellite aloft. Aluminum foil and plastic skin, less than .001 inch thick, cost 65 cents.

•

About half the scientific manpower of ARPA is now working on far-ranging anti-missile defense schemes.

•

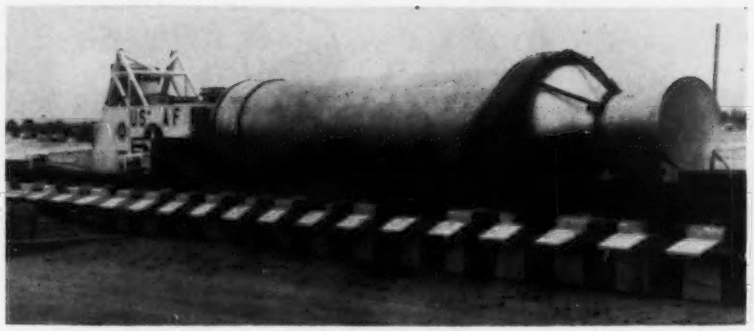
Lacrosse goes operational within the next two months: at Fort Sill, Okla.

•

Discoverer II capsule was of oblating plastic, 33 x 27 in., weighed 160 lb., contained oxygen supply and scrubbers to take out CO_2.

•

Ultrasonic delay lines developed by Corning Glass Works will store a signal with minimum attenuation for periods ranging from less than 50 to more than 15,000 microseconds.



Solid propellant rocket manufactured by Astrodyne Inc., McGregor, Texas, can propel 2,000 lb test sled over 1,200 mph. Called "Megaboom," it has engine and igniter in forward end, fixed straight nozzle on aft end, is ready for instantaneous firing after two years' storage.

MISSILE I.Q.

Relatively new entrants for your lexicon of current projects and missiles:

Nova—seven stage rocket which may take a man to the moon within four years.

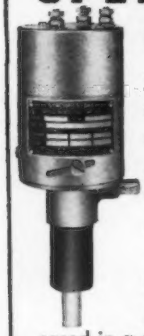
Vega—missile to carry three ton satellites into orbit. May be used for shot at Venus in 1960.

Saturn—ARPA's super-booster (1,500,000 lb thrust).

Project HETS — Air Force's High Environmental Test System, cost-paring method of testing missile equipment at low altitude.

Mauler — Army's tactical air defense missile which may assigned to a contractor soon.

TWO ELEMENT SPEED SENSITIVE SWITCHES



The Synchro-Start Models GH-2 and GS-2 governors contain two snap action switches to be used for opening or closing circuits at any RPM over 500.

They contain sealed ball bearings, are adjustable while running and are encased in a splash proof housing. These two switch governors are supplied for the standard SAE tachometer drive or distributor take-off and for AND20005 engine pad mounting (GA Series).

Other Synchro-Start governors are available with one and three switches with a variation of mountings.

SYNCHRO-START PRODUCTS, INC.
8151 NORTH RIDGEWAY AVENUE, SKOKIE, ILLINOIS
Manufacturers of
AUTOMATIC ENGINE CONTROLS • SPECIAL CONTROL PANELS
SAFETY ALARM SETS • D.C. SOLENOIDS • HEAVY DUTY RELAYS

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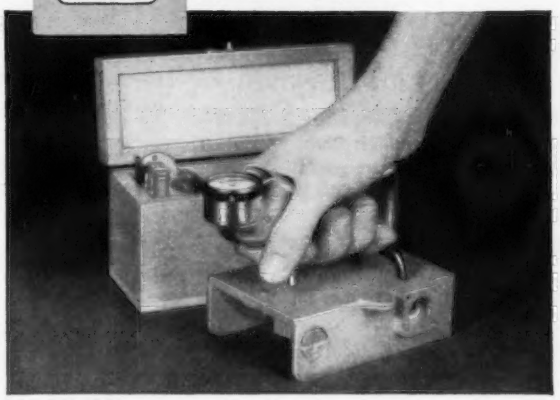
THE MARK OF QUALITY
BARBER COLMAN

Impressor
PORTABLE HARDNESS TESTER
- Rapid testing — no setup
- Easy to carry and use
- Needs only space for hand



A portable hardness tester for aluminum alloys, soft metals, and plastics, the Barber-Colman Impressor is designed for fabricated parts and raw stock testing. Operating experience is not essential. The reading is instantly indicated on the convenient dial. No waiting, preloading, or separate measurements. Barber-Colman engineers will gladly recommend the most suitable model for your application. Write today for complete details.

BARBER-COLMAN COMPANY
Dept. Q, 1210-9 Rock Street, Rockford, Illinois

Circle 43 on Inquiry Card, page 83

april 29-may 1
metals engineering conference
american society of mechanical engineers
albany, n. y.

◆

april 30-may 1
controllable satellites conference
american rocket society
M.I.T., cambridge, mass.

◆

may 4-6
national aeronautical electronics conference
institute of radio engineers
biltmore hotel, dayton, o.

may 6-9
15th annual national forum
american helicopter society
sheraton park hotel, washington, d. c.

◆

may 10-16
annual meeting
aviation writers asso.
washington, d. c.

◆

may 18-21
national conference
society of aeronautical weight engineers
hotel henry grady, atlanta, ga.

May 20-22
national spring meeting
society for experimental stress analysis
sheraton park hotel, washington, d. c.

◆

may 25-27
production & quality control exposition and 13th annual convention
american society of quality control
cleveland, o.

◆

may 25-27
telemetering conference on space
A.R.S., I.A.S., A.I.E.E., I.S.A.
denver, colo.

◆

may 25-28
design engineering show
american society of mechanical engineers
convention hall, phila.

◆

may 26-28
supersonic transport meeting
san diego section, inst. of the aeronautical sciences
san diego, calif.

◆

june 8-11
semi-annual meeting and astronautical exhibition
american rocket society
el cortez hotel, san diego, calif.

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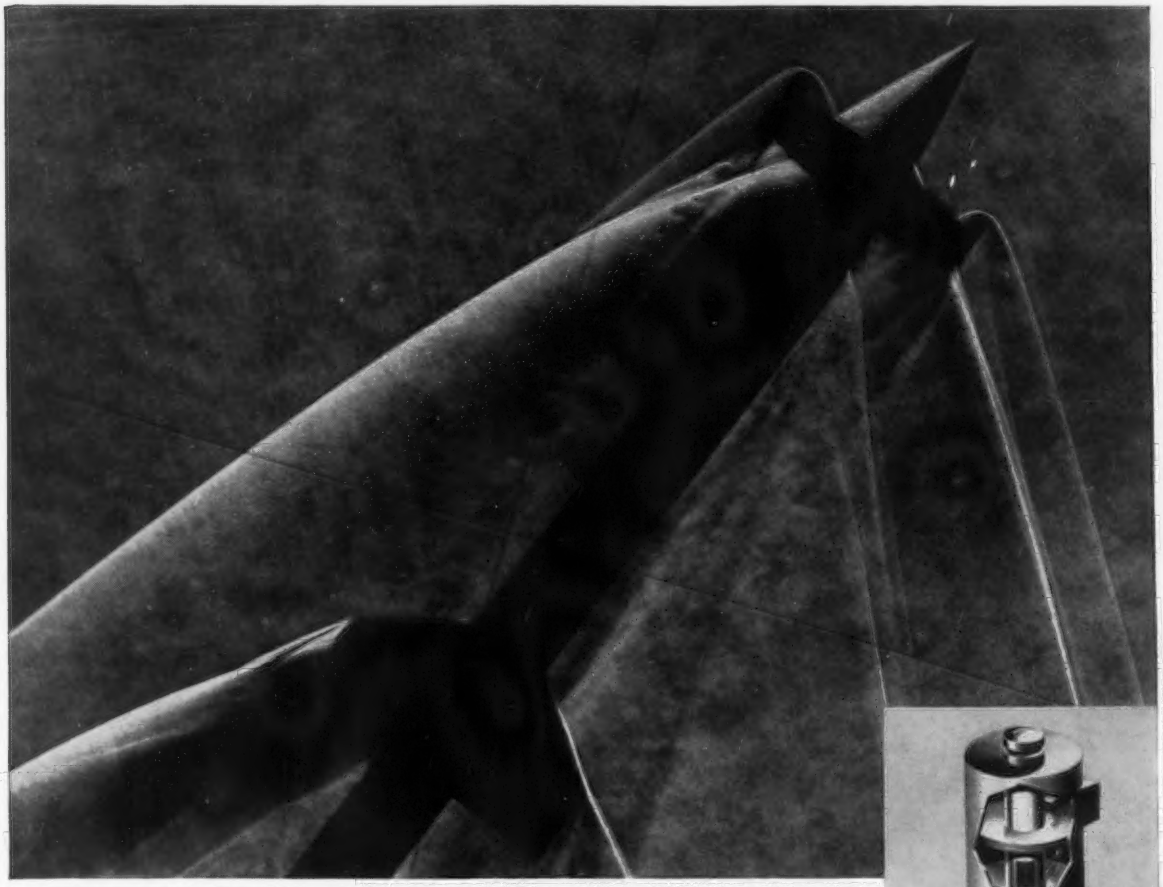


In the wind tunnel of the Naval Supersonic Laboratory at M.I.T., a missile model is subjected to speeds of several Mach numbers. B-L-H SR-4 bonded wire strain gages report longitudinal and latitudinal stresses, drag, lift, etc., with high accuracy.

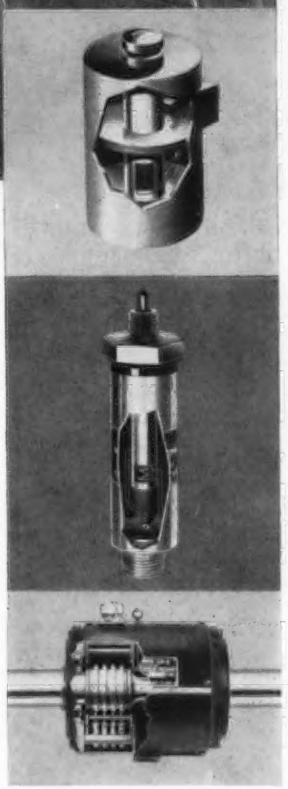
B-L-H ELECTRONIC TRANSDUCERS measure forces with new ease and accuracy

With the arrival of the Space Age have come increasingly severe demands on measuring instrumentation for precision and versatility. Accurate center of gravity computations, for example, are now more than important—they are vital.

B-L-H SR-4® transducers are highly responsive, durable and adaptable. Stock units offer long-term accuracy of ±1/10% and repeatability of ±1/20%. They will measure any forces involving tension or compression, torque, etc. With appropriate instrumentation, they can also determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. The type and number of applications are virtually unlimited.

The heart of every B-L-H transducer is its SR-4 bonded wire strain gages. They are bonded to a metal element in the transducer and approximately 10 milliamperes is fed through them. They receive the same strains as the transducer when a force is applied. Their electrical resistance changes in linear relationship with strain. The voltage output can be calibrated directly in terms of load—or fed into any common types of instrumentation, such as dial indicators, graphic recorders, digital printers, computers, etc.

For more information on SR-4 electronic transducers—load cells, pressure cells, or torque meters—ask to have a B-L-H man call on you—or write on your company letterhead for a copy of "Modern Force Measurement." Address Dept. 17-E.



(top to bottom) Load cell, pressure cell, and torque meter transducers.

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

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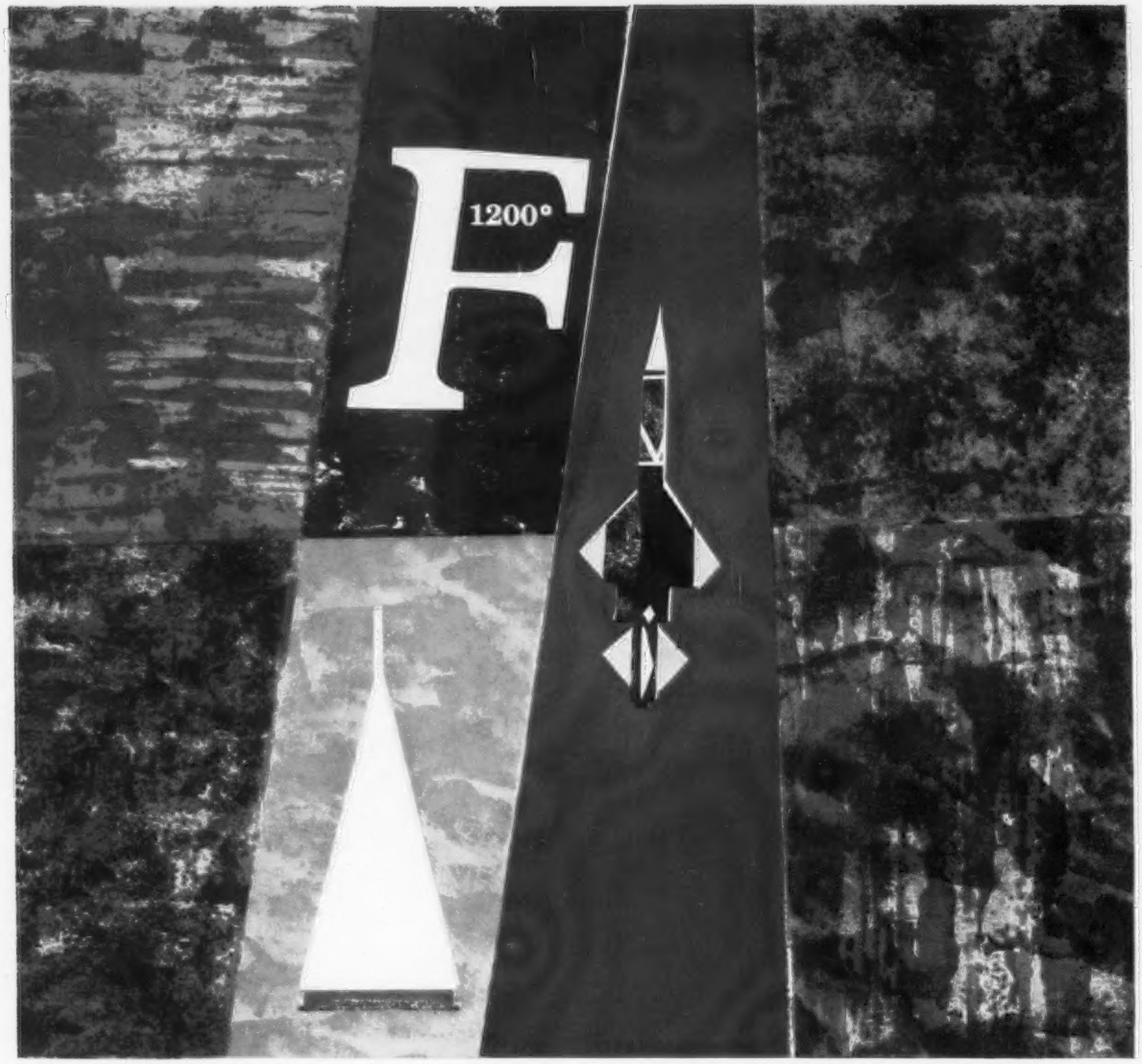

BRUNSWICK "SHOOTS" THE RADOME RANGE TO 1200° F

Brunswick makes a new breach in the thermal barrier with newly developed non-metallic materials that boost the temperature tolerance of radomes and nose cones to 1000-1200°F for limited exposure periods – almost twice the previous limit. This new advance in Brunswick's Strickland 'B' Process of filament winding opens a new chapter in aircraft and missile designing.

New "SBP" filament winding results in the highest strength-to-weight ratios ever obtained in radomes and nose cones with significant weight savings over conventional structures. With unmatched electrical uniformity, Brunswick builds them to meet the tightest tolerances for dielectric constants and compound configurations. Brunswick offers full electronic testing facilities.

Brunswick radomes and nose cones now slice skyward on such supersonic aircraft as the advanced Convair F-106; on such missiles as the Boeing Bomarc and Lockheed Q5. For details on Brunswick's leadership in research, development and testing, write: The Brunswick-Balke-Collender Company, Defense Products Division, 1700 Messler St., Muskegon, Mich.

BRUNSWICK

MAKES YOUR IDEAS *WORK*

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